SMART WEAPONS OPERABILITY ENHANCEMENT
USAF
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SWOE



# Standard Scenes Measurement Analysis & Modeling

Anne-Marie L. LaHale, David E. Strang
and Robert K. Baratono

Keweenaw Research Center
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SWOE Report 91-15
29 July 1991

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## FOREWORD

SWOE Report 91-15, 29 July 1991, was prepared by A.L. LaHaie, D.E. Strang and R.K. Baratono of Keweenaw Research Center, Michigan Technological University, Houghton, Michigan.

This report is a contribution to the Smart Weapons Operability Enhancement (SWOE) Program. SWOE is a coordinated, Army, Navy, Marine Corps, Air Force and DARPA program initiated to enhance performance of future smart weapon systems through an integrated process of applying knowledge of the broadest possible range of battlefield conditions.

Performance of smart weapons can vary widely, depending on the environment in which the systems operate. Temporal and spatial dynamics significantly impact weapon performance. Testing of developmental weapon systems has been limited to a few selected combinations of targets and environment conditions, primarily because of the high costs of full-scale field tests and limited access to the areas or events for which performance data are required.

Performance predictions are needed for a broad range of background environmental conditions and targets. Meeting this need takes advantage of significant DoD investments by Army, Navy, Marine Corps and Air Force in 1) basic and applied environmental research, data collection, analysis, modeling and rendering capabilities, 2) extensive target measurement capabilities and geometry models, and 3) currently available computational capabilities. The SWOE program takes advantage of these DoD investments to produce an integrated process.

SWOE is developing, validating, and demonstrating the capability of this integrated process to handle complex target and background environment interactions for a world-wide range of battlefield conditions. SWOE is providing the DoD smart weapons and autonomous target recognition (ATR) communities with a validated capability to integrate measurement, information base, modeling and scene rendering techniques for complex environments. The result of a DoD-wide partnership, this effort works in concert with both advanced weapon system developers and major weapon system test and evaluation programs.

The SWOE program started in FY89 under Balanced Technology Initiative (BTI) sponsorship. Present sponsorship is by the U.S. Army Corps of Engineers (lead service), the individual services, and the Joint Test and Evaluation (JT&E) program of the Office of the Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense (OSD).

The Program Director is Dr. L.E. Link, Technical Director of the U.S. Army, Cold Regions Research and Engineering Laboratory (CRREL). The Program Manager is Dr. J.P. Welsh, CRREL. The Integration Manager is Mr. Richard Palmer, CRREL. The task areas and their managers are as follows: Modeling Task Area, LTC George G. Koenig, USAF, Geophysics Laboratory (GL), of the Air Force Phillips Laboratories; Information Bases Task Area, Mr. Harold W. West, PE, U.S. Army Engineer, Waterways Experiment Station (WES); Scene Rendering Task Area, Mr. Mike Hardaway, Corps of Engineers, Topographic Engineering Center (TEC); Validation Task Area, Dr. Jon Martin, Atmospheric Sciences Laboratory (ASL) of the Army Materiel Command.

# PREFACE

The work described in this report was performed as part of the Basic Technologies Initiative Smart Weapons Operability Enhancement (BTI/SWOE) program, under contract number DACA89-89-K-0012 managed by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL).

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# 1.0. INTRODUCTION

The work described in this report was performed as part of the Smart Weapons Operability Enhancement (SWOE) program, a cooperative tri-service research effort funded as part of the Basic Technology Initiative (BTI) program. Among the primary goals of the BTI/SWOE program have been development of a quantitative treatment of the environment in critical spectral bands, and the collection, evaluation, and integration of representative data and information bases. KRC's participation in the BTI/SWOE program has included contributions in the program's three primary developmental areas:

1. Background measurement and characterization;
2. Information data base;
3. Modeling - scene metrics.

## 1.1 Background Measurement and Characterization

Environmental conditions significantly affect the thermal infrared signature of targets, and the detectability of those targets by sensors operating in the $8 - 14\mu m$ range. The collection of detailed measurements of the background environment, and the analysis of those measurements in order to characterize the background are important preliminary steps toward incorporating a comprehensive understanding of the environment to the design and testing of smart weapons systems.

As part of a cooperative data collection and information exchange effort of the BTI/SWOE, Keweenaw Research Center (KRC) participated in the 1990 Forest Ecosystem Dynamics - Multisensor Aircraft Campaign (FED MAC) project, conducted at the International Paper National Experimental Forest (NEF), near Howland, Maine. This work was conducted in order to acquire information useful for model validation, and for establishing the needs and directions of future BTI/SWOE measurement programs.

KRC collected thermal, optical, radiative and meteorological measurements of forest canopy elements to support the following objectives:

1. Model vegetative leafy canopies with emphasis on conifers;
2. Investigate the soil temperature distribution along the forest edge;
3. Model "twiggy" canopy with emphasis on a single, deciduous tree.

From 0800 on 9 September, 1990 to 1330 on 11 September, 1990, KRC personnel recorded thermal imagery at two sites, on an hourly basis, with additional imagery recorded during periods of particular interest. During this same time period, extensive meteorological and soil temperature data were also recorded. The sites selected and data collected in support of each objective are discussed separately below, in Section 5.1.1.

## 1.2 Information data base

Among the long-term goals of the BTI/SWOE program is that of assembling and validating environmental databases, tailored for weapon development, test and evaluation.[1] The generation of such an information database involves two preliminary, general areas of endeavor. It is necessary to develop a database structure to accommodate the large amount of information collected during measurement and characterization activity. More analytical work is required to determine possible scene conditions and features of interest, those scene conditions most likely to occur, and those that are most significant to the function of target detection.

The U.S. Army Tank-Automotive Command (TACOM) Standard Scenes data base,[2] developed by KRC, represents a compendium of ground truth, scene component data, meteorological data and concurrent, calibrated infrared imagery for six scenes. Data had been collected on these scenes for full diurnal cycles at different times across 3 years, thus affording information about the scenes under a range of meteorological and seasonal conditions. General climate and physical features of Standard Scenes are comparable to those of parts of Germany.[3] Inasmuch as German sites represented one of the three scenarios of interest in the BTI/SWOE program (the other scenarios being desert and tropical), the Standard Scenes data base provides relevant information. KRC's experience with developing this database also provides a useful basis for appraisal of database developmental needs and directions.

## 1.3 Modeling and simulation

The design, development, and testing of smart weapons can benefit from greater understanding of the variations in radiometric properties of natural background scenes. These variations reflect some underlying, physical variation of the background. Describing scene components directly in terms of their image properties allows more general measures of shape, intensity, texture, and spatial arrangement to be the critical factors in discriminating between different scene elements.

Predicting radiometric variability of natural backgrounds involves several activities. First, the radiometric properties of specific scene elements must be determined. The covariation between these radiometric properties and related, quantifiable scene characteristics - e.g., material properties, meteorological, climatic, and atmospheric conditions, and time - must be evaluated. On the basis of this information, algorithms to predict variations in the radiometric properties of specific scene elements can be developed. Finally, the interaction between radiometric and physical properties of the scene and sensor system performance is evaluated.

### 1.3.1 Scene Metrics

Performance goals of automatic target recognition algorithms are to detect and select targets in real time, and to be able to adapt to dynamic physical and tactical situations. Testing ATR algorithms under a range of physical conditions involves: 1) specifying an appropriate data base, 2) training and evaluating feature classification algorithms and decision criteria on the data base to determine the most efficient sets of algorithms for specific task objectives, and 3) determining the requirements for data bases of imagery representative of specific scenarios.

# 2.0. OBJECTIVES

## 2.1 Background Measurement and Characterization

KRC provided personnel, equipment, and facilities to conduct measurements of natural backgrounds, including 1) site composition inventory, and 2) time-dependent, calibrated thermal imagery, with simultaneous weather and scene parameter measurements, in support of the cooperative data acquisition and exchange program involving BTI/SWOE and the Forest Ecosystem Dynamics/Multisensor Aircraft Campaign (FED MAC) experiment.

### 2.1.1 FED MAC Field Test Objectives

The FED MAC experiment, conducted at International Paper's Northern Experimental Forest near Howland, Maine, included several specific objectives relating to radiative transfer processes in northern/boreal forest ecosystems. These objectives included developing a better understanding of the transfer and utilization of radiation in forest canopies, and enhancing the development of quantitative modeling of radiative transfer process in northern forest environments.[4] These objectives were to be achieved through collection of detailed field experimental data. Specific objectives defined for KRC participation in the FED MAC project are detailed below.

**Vegetative Leafy Canopies: Edge Dynamics.**

The thermal behavior along the edge of a natural forest, at its interface with open, grassy field, was to be investigated. A particularly interesting feature of the site selected for this purpose was a large, narrow gap in the forest edge, which afforded a clear view of the forest interior. In addition to characterizing the site, immediate field test objectives were to collect measurements and thermal imagery of 1) simple, homogeneous (*i.e.*, single species) portions of the forest canopy, viewed from short-range or in magnification, 2) clumps of single-species vegetation along the edge, viewed from short- to intermediate-range, and 3) mixtures of deciduous and coniferous species in the forest canopy. The goals of obtaining this imagery

were to document thermal infrared radiance patterns of component parts of the forest canopy, and to provide data to support simulation of canopy temperature patterns.

**Soil Temperature Transect into Forest Edge.**

The objective of performing a soil temperature transect was to monitor soil temperatures at various points, from an exposed area in an open field to points progressively deeper within the forest canopy. Thermocouple probes had to be devised to measure and record a profile of soil temperature at various depths.

**Single, Isolated Tree Thermal Response.**

Thermal infrared imagery and supporting weather data were acquired by KRC to support an investigation of the thermal response of an individual tree, conducted by Sparta, Inc. The purpose of this effort was to document thermal response of component parts of a single tree to transient changes in environmental conditions.

## 2.2 Information data base

The Standard Scenes database was to be organized and structured to make it compatible with modeling community needs. The Standard Scenes database was to be made available to the modeling community.

On the basis of experience gained from establishing the Standard Scenes database, KRC was to provide ideas to help develop a database structure that would accommodate the large amount of information collected during measurement and characterization activity.

## 2.3 Modeling and simulation

In the context of BTI/SWOE goals regarding the prediction of radiometric variablility, KRC was to assist in calculating statistics for scene structure, and in adapting or improving infrared models/software to include calculation of various measures of scene characteristics. The Physically Reasonable Infrared Signature Model (PRISM) was also to be delivered and integrated to the initial BTI/SWOE software capabilities.

### 2.3.1 Scene Metrics

In the context of BTI/SWOE goals regarding scene structure vs. metrics, KRC was to function in a support role, assisting in the analysis of selected infrared scene metrics and

other measures of image and scene elements that are linked to background material properties. Infrared models/software already developed by KRC were to be improved to compute additional statistics describing scene features, and measures such as scene clutter.

# 3.0. CONCLUSIONS

## 3.1 Conclusions - Background Measurement and Characterization

KRC participation in the FED MAC experiment has generated thermal infrared imagery and supporting measurements that are being incorporated to the database being established cooperatively for that effort. The imagery and field data have been reduced to computer files and analyzed by KRC personnel. Results of the study of forest edge dynamics, and the soil temperature transect of the forest edge are discussed in the context of this report. In its support capacity for the study of thermal response of a single tree, KRC has provided imagery, digitized image files, and supporting data to Sparta, Inc. Copies of thermal infrared imagery have also been provided to C2NVEO.

KRC also prepared for participation in another BTI/SWOE field test which was originally planned to take place in Yuma, Arizona, in August, 1990.

## 3.2 Conclusions - Information Data Base

The Standard Scenes database developed by KRC was made available for integration to the BTI/SWOE information base.

Interaction between agencies cooperating in BTI/SWOE program has provided insight to the information needs and format requirements of the modeling community, at large.

## 3.3 Conclusions - Modeling and Simulation

The PRISM software was made available for integration to the BTI/SWOE suite of modeling and simulation packages. The newest release of PRISM provides full three-dimensional faceted representation of a vehicle, and has been enhanced by the inclusion of the following

capabilities: facet-to-facet radiation exchange, multiple bounce solar radiation, long- and short-wave shadowing, multiple bounce radiosity, and target signature visualization. This 3-D version of PRISM is available as of July, 1991.

The principal application of PRISM is the predictive modeling of the thermal signatures of military vehicles; it previously had not been used for background scene generation, and hence was not evaluated in detail in the context of the BTI/SWOE program.[5] A modified version of PRISM is presently being developed to predictively model thermal behaviour of natural objects, e.g., a tree, and natural terrain. The database created as part of participation in the BTI/SWOE "Background Measurement and Characterization" activities provide quantitative information useful in the process of developing and validating these models.

In its support role regarding scene metrics, KRC tested a Pascal program developed by Waterways Experiment Station, "SCENEMEZ", on selected Standard Scenes imagery. Discussion relating to this effort is provided both in the main body of this report, and also in Appendix D.

# 4.0. RECOMMENDATIONS

## 4.1 Recommendations - Background Measurement and Characterization

The original Standard Scenes database did not include measurements of long-wave incoming radiation, although subsequent KRC field tests do include this variable. It is useful in prediction of radiometric variability, and is incorporated in computations in PRISM and related codes. From test to test in a given site, it is recommended that the following parameters be measured and recorded at appropriate frequencies (suggested frequencies are shown), and in a consistent format:

1. Geophysical and meteorological parameters (see Section 5.1.3.; twelve times per hour)
2. Vertical profiles of soil and air temperature and three-axis wind velocities, at various points in the scene (12 times per hour)
3. Snowpack thermal profile (if applicable; 12 times per hour)
4. Water content of scene surface (once per hour)
5. Spot radiometric measurements of selected scene component surfaces (once per hour, or as local conditions dictate)
6. Soil moisture profile (dependent on precipitation; 4 times per diurnal test)
7. Tree canopy leaf area index (LAI) (if applicable; twice per diurnal test)
8. Vegetation status (once per test)

Characterization of the atmosphere or the monitoring of other thermal and millimeter wave properties of scene components should be determined by the importance of evaluating such factors as sensor system characteristics and the range at which sensors are expected to operate.

## 4.2 Recommendations - Information Data Base

Thermal infrared imagery obtained at intermediate range and from elevated or aerial perspective with varying depression angles is definitely of interest in applications involving smart weapons. Standard Scene VI is the only scene in the KRC database that affords a lookdown perspective from a significant elevation. Although the BTI/SWOE effort has served to bring together a variety of scenes from disparate data bases, further development and characterization of scenes imaged at various ranges and depression angles is recommended, as well as the incorporation of blackbodies at various ranges for calibration purposes.

## 4.3 Recommendations - Modeling and Simulation

Continuing problems include the difficulty in obtaining source code for programs, programs that contain machine-specific commands that require adaptation to run on different systems, and programs that contain proprietary subroutines that are difficult to obtain or difficult to integrate on a different system. Every effort should be made to further the goals of standardization, and complete documentation of subroutines and subprograms to ease the work of adapting software to new systems.

Continued development of three-dimensional, first principles models of natural backgrounds should remain a strong goal of this program. Refinement of techniques for assessing target recognition performance in the infrared domain is also recommended.

# 5.0. DISCUSSION

## 5.1 Background Measurement and Characterization

### 5.1.1 Advance Preparation for Field Testing

Preparation for field work on background characterization involved several significant activities, including remodeling the interior and exterior of the KRC mobile lab/equipment bus, shown in Figure 5.1 to condition it for travel to remote field test sites. Some alterations to the lab/bus were made for the purposes of safety: high intensity driving lights were installed for improved vision in fog, snow, or night driving; back-up lights and more visible turn signals were installed; a mechanical-ride driver's seat was put in; and a weather radio and speakers were installed to provide weather monitoring and warnings during field tests. A new heater was also installed, along with a separate battery and battery isolator to operate the heater in case of power failure. Other alterations enhanced the capabilities of the mobile lab: the vehicle was wired to accept 120 vac. shore or generated power including a circuit breaker panel with a relay to switch to either generated or shore power; electrical strip outlets to power equipment were installed; interior lighting was improved; and a higher output alternator was installed to accommodate new accessories. A final series of alterations improved equipment storage and accessibility on the lab/bus.

Table 5.1 lists principal equipment provided by KRC for the FED MAC experiment. The AGEMA infrared scanning system was acquired for this project. The twelve ground surface thermocouples included in the Meteorological Station listing were specifically devised for the soil temperature transect detailed in Section 5.1.3. Post-hoc analysis of equipment requisites for the FED MAC test showed the equipment list to be adequate; possible additions would be to include more sets of blackbodies, shielded thermocouples on individual stands, and portable spot radiometers.

### 5.1.2 Field Test Sites and Details of Experimental Plans

KRC set up equipment and performed measurements at two sites in the International Paper National Experimental Forest (NEF), near Howland, Maine. As described in following sections, the two sites are near to each other and data was recorded consistently and with near simultaneity at both sites across a two and a half day period. The KRC primary site was set up to provide data relating to the objectives of studying edge dynamics of vegetative leafy canopies, and of investigating changes in soil temperature in the forest edge. The KRC secondary site provided data supporting the investigation of thermal dynamics of an individual tree.

**KRC Primary Site.**

The primary site for KRC measurement activities is located north of the NEF calibration ("CAL") site, and west of the tree seed orchard, as shown in Figure 5.2. This site was selected for several reasons: 1) it affords a good perspective of a forest edge, 2) the forest edge includes a good mix of deciduous (predominantly yellow birch and poplar) and coniferous (spruce and hemlock) species, and 3) a large gap in the forest edge affords opportunities both for imaging the forest interior, and also for investigating the dynamics between the forest's edge and interior.

The KRC primary site is located in an open field that slopes slightly down to a treeline having a south-by-southeastern exposure. The field is comprised of patches of grassy vegetation, mosses, and bare sandy or rocky soil. The forest edge is dominated by younger, deciduous trees and bushes; behind and above these, the crowns of more mature, predominantly coniferous trees are clearly visible. The gap in the vegetation at the forest edge measures 9 feet at its narrowest spot, and affords a clear view of the trunks and crowns of large spruce and hemlock in the forest's interior.

Infrared imagery of the forest edge and gap was obtained from two points, as shown in the site schematics in Figures 5.3 and 5.4. The soil temperature transect was established in the gap area. Figure 5.5 provides a schematic of the soil probe placement, and identifies probes both by thermocouple depth and by the channel on which their output was recorded. The KRC meteorological tower and station were also set up at this site. The photograph in Figure 5.6 provides a visual perspective of the KRC primary site.

**KRC Secondary Site.**

The secondary site for KRC measurement activities is located adjacent to the NEF calibration ("CAL") site, just south of the monitoring equipment building (see Figure 5.2). This site was the location of the single poplar tree (*Populus grandidentata*) selected for study by Sparta, Inc. Sparta personnel conducted extensive measurements on this tree and placed a large number of thermocouples on it. KRC supplemented the Sparta thermal measurements with thermal imagery of the tree, along with meteorological data recorded at the KRC primary site.

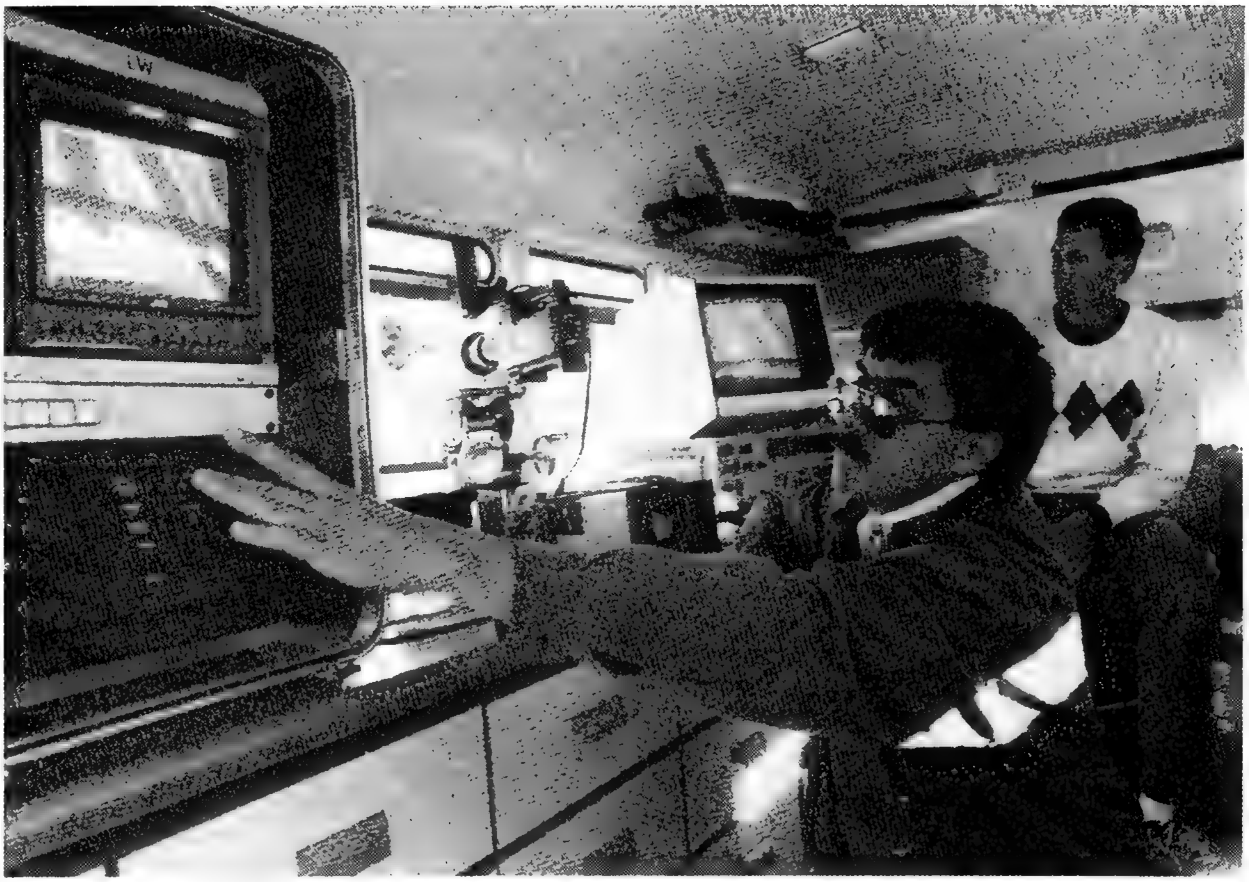


**Figure 5.1: KRC Mobile Lab/Equipment Bus Interior, Photographic View**

KRC personnel are shown setting up and testing equipment inside the mobile lab. At the study site in the Northern Experimental Forest, Maine, this equipment was used to record thermal infrared imagery of a natural, forested background scene, and related physical measurements.

**Table 5.1: Principal equipment provided by KRC for the FED MAC experiment.**

Keweenaw Research Center Equipment List

| Item | Serial # | MTU Tag |
|---|---|---|
| Meteorlogical Station | | |
| IBM PC computer | | 59597 |
| IBM PC monitor | | 64576 |
| EPSON printer | 512301 | |
| DORIC Digitrend 235 | | 61806 |
| AMS-5PA Amplifier | 1333 | |
| Voltage stabilizer | | 81887 |
| Multipoint Selector | | 61798 |
| IR Sensors(3) | 26480F3 (1) | 67665, 67666 (2) |
| Wind Speed Velometer | | 61835 |
| 10m portable weather tower | | |
| Ground probe | | |
| 12 ground surface thermocouples | | |
| Honda (6kw) generator | | 67669 |
| Blackbody Ambient | | |
| Blackbody Heated | | 69850 |
| Campbell Thermocouple loggers(2) | | 65860, 67656 |
| 12V batteries for loggers(2) | | |
| Infrared Scanning Equipment | | |
| Inframetrics 610 IR Camera | 7133 | |
| Inframetrics 3× lens | 7133 | |
| JVC Monitors | | 67747, 67748 |
| Inframetrics Controller | | 67749 |
| Agema IR Scanner w/lens | 003005 | |
| Agema Controller | 00272 | |
| Agema Power Supply(s) | 3249, 90068, 90069 | |
| Agema Monitor | 001043 | |
| Monitor | | 61829 |
| Sanyo Monitor | 12104034 | |
| Barnes radiometer | | 62103 |
| Tektronix 2213 Oscilloscope | | |
| Recording Equipment | | |
| SONY VO-7600 U-matic recorders | | 15819, 15494 |
| U-matic recording tapes | | |
| Video Camera (VCR) | | |
| VHS tapes | | |
| Miscellaneous | | |
| Toshiba portable computer | | 71332 |
| Honda generator in bus | | 64141 |
| Sanyo microwave oven | | |
| Tool Kit | | |
| Dewer, 30L (2) Liquid Nitrogen | | |
| Dewer, 5L (2) Liquid Nitrogen | | |
| 3.5in and 5.25in diskettes | | |
| Realistic TRC210 radios(2) | | 61857,61864 |
| LICOR LAI-2000 in case | below | |
| LAI-2700 logger | | 71333, 71334 |
| LAI-2500 radiation detector | | 71335, 71336 |
| Misc. connectors, cables | | |

The KRC secondary site is an open area from which dense, bushy vegetation – e.g., blackberry bushes, poplar saplings and other small, deciduous trees – had been recently removed in order to isolate the single poplar selected for study. KRC imaging equipment was set up to the northwest of the tree, as shown in the site schematic in Figure 5.7 and the photograph in Figure 5.8.

### 5.1.3 Data Acquisition

**Calibrated Thermal Imagery.**

Thermal imagery was collected using two commercially available IR imaging systems: an Inframetrics model 610 was used at the primary site, and an AGEMA Thermovision 880 at the secondary site. Specifications for the imagers are detailed in Table 5.2. Each frame of thermal imagery is reference to an apparent temperature or blackbody equivalent temperature standard via the near simultaneous acquisition of frames showing a pair of blackbodies, one of which is maintained at ambient temperature and the other heated to a temperature near the warmest observed in the scene. The temperature of the heated blackbody is actively controlled, and both blackbodies are monitored with thermocouples that are read directly into the weather data logger.

**Field Test Procedure.**

Soil probes were placed on 7 September, 1990, and thus had more than 24 hours to re-equilibriate before data was recorded. As may be seen in Figure 5.9, the soil around the first probe was disturbed during the placement procedure. The other probes were placed with much less disturbance of the soil, as may be seen in the photographs in Figures 5.10, 5.11, and 5.12. In addition to the weather variables discussed in the following section, the KRC meteorological station computer recorded data for all 12 soil probes transecting the forest edge, the main soil probe located near the meteorological tower in open field, shown in Figure 5.13, and the shielded thermocouple for measuring air temperature that was placed at the forest edge, as shown in Figure 5.14. Measurements were automatically recorded every five minutes.

Thermal imagery was recorded at hourly intervals, or more frequently during periods when environmental conditions caused thermal activity in the scenes to change or vary. At the KRC primary site, calibrated thermal imagery included views of the following scenes: gap area (1X lens), an area to the left of the gap with predominantly deciduous trees (3X lens), a close-up view of the gap (3X lens), and an area to the right of the gap with a mix of deciduous and coniferous species (3X lens). At the KRC secondary site, calibrated thermal imagery was taken of the lower half of the isolated tree, and occasionally of the upper half of the tree.

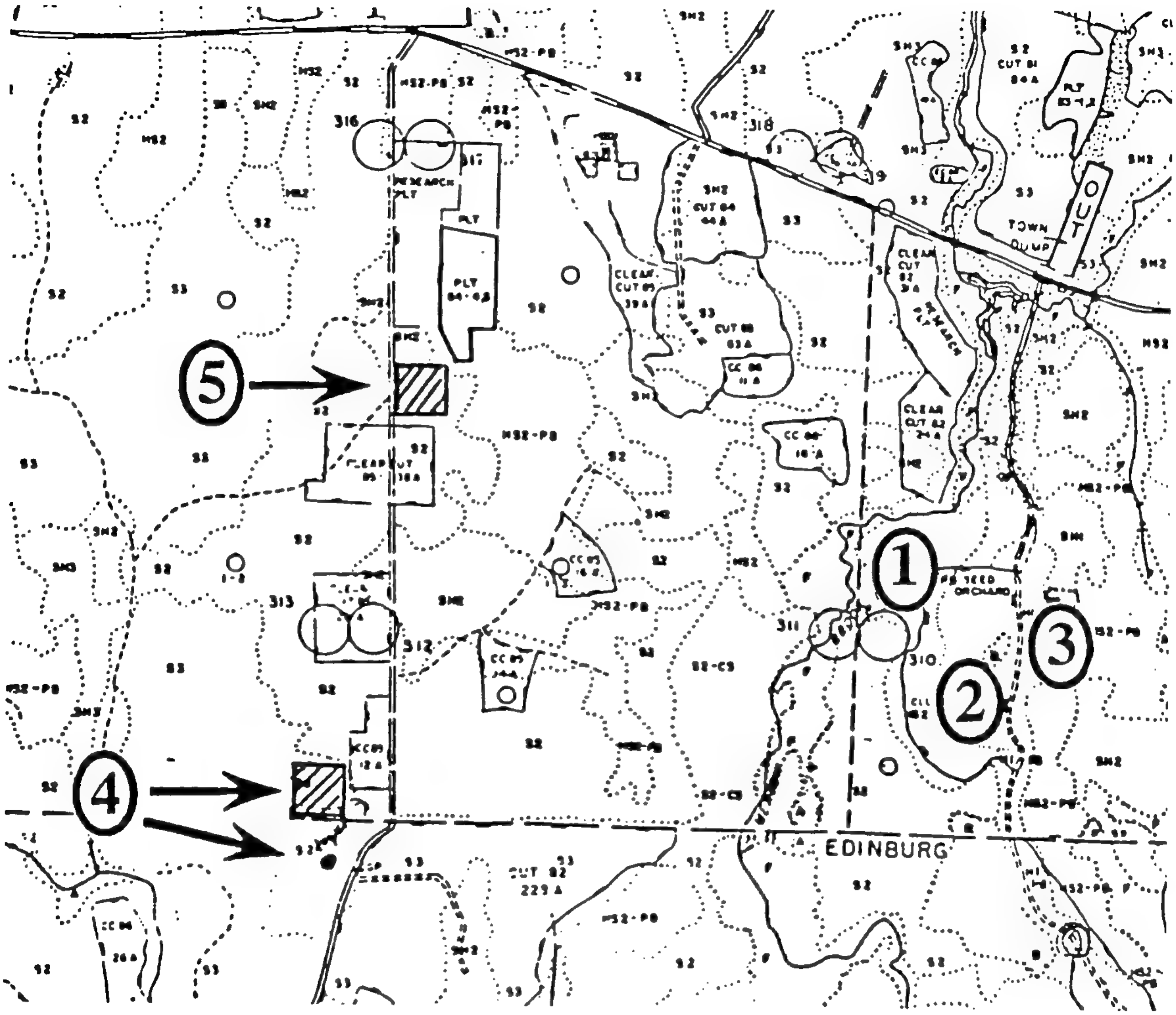



**Figure 5.2: Map of International Paper's Northern Experimental Forest.**

1. KRC Primary Site
2. Calibration Site (KRC Secondary Site)
3. Esker Site
4. Spruce Site (top)
   Tower Site (bottom)
5. Hemlock Site

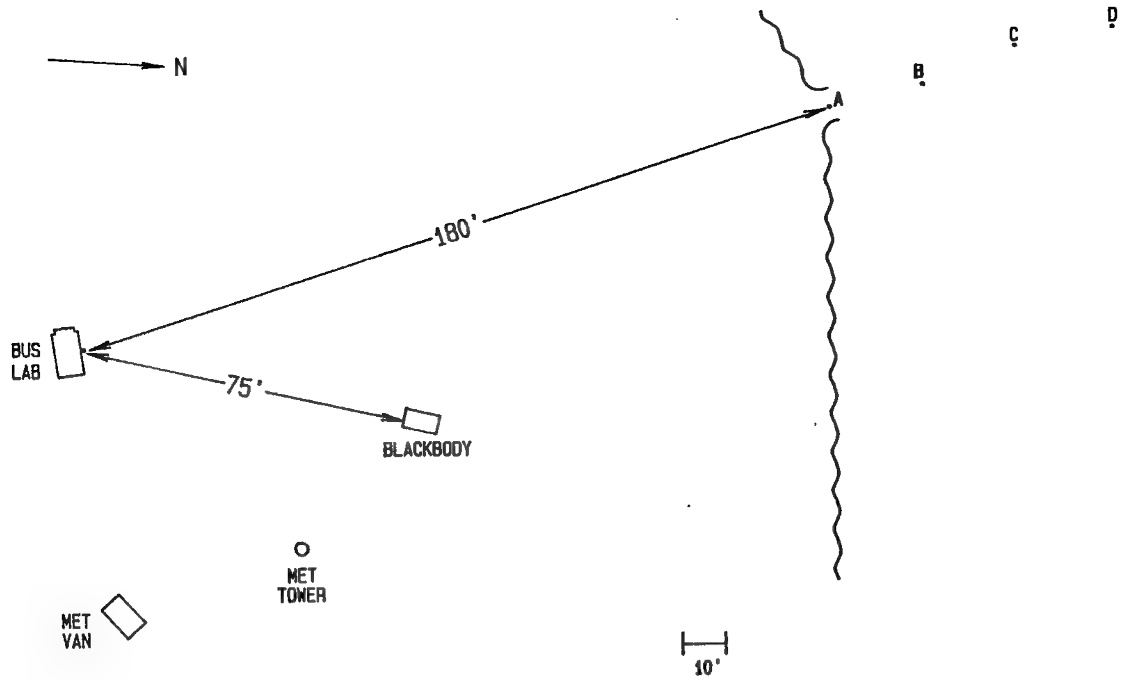



**Figure 5.3: Schematic of KRC Primary Site, 09 September, 1990.**
Positioning of soil probes, blackbodies, weather station and van, and imaging bus lab are shown in relation to the forest edge, as they were for imagery taken during the first 24 hour cycle of the field test.

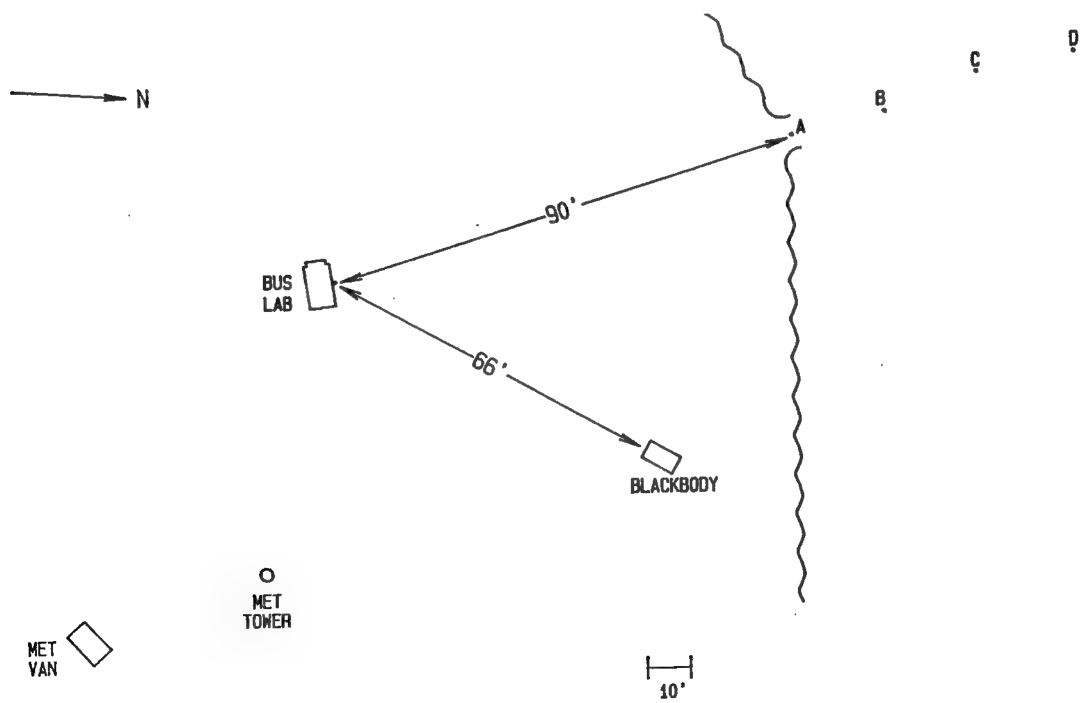



**Figure 5.4: Schematic of KRC Primary Site, 10 September, 1990.**
Positioning of soil probes, blackbodies, weather station and van, and imaging bus lab are shown in relation to the forest edge, as they were for imagery taken during the second 24 hour cycle of the field test.

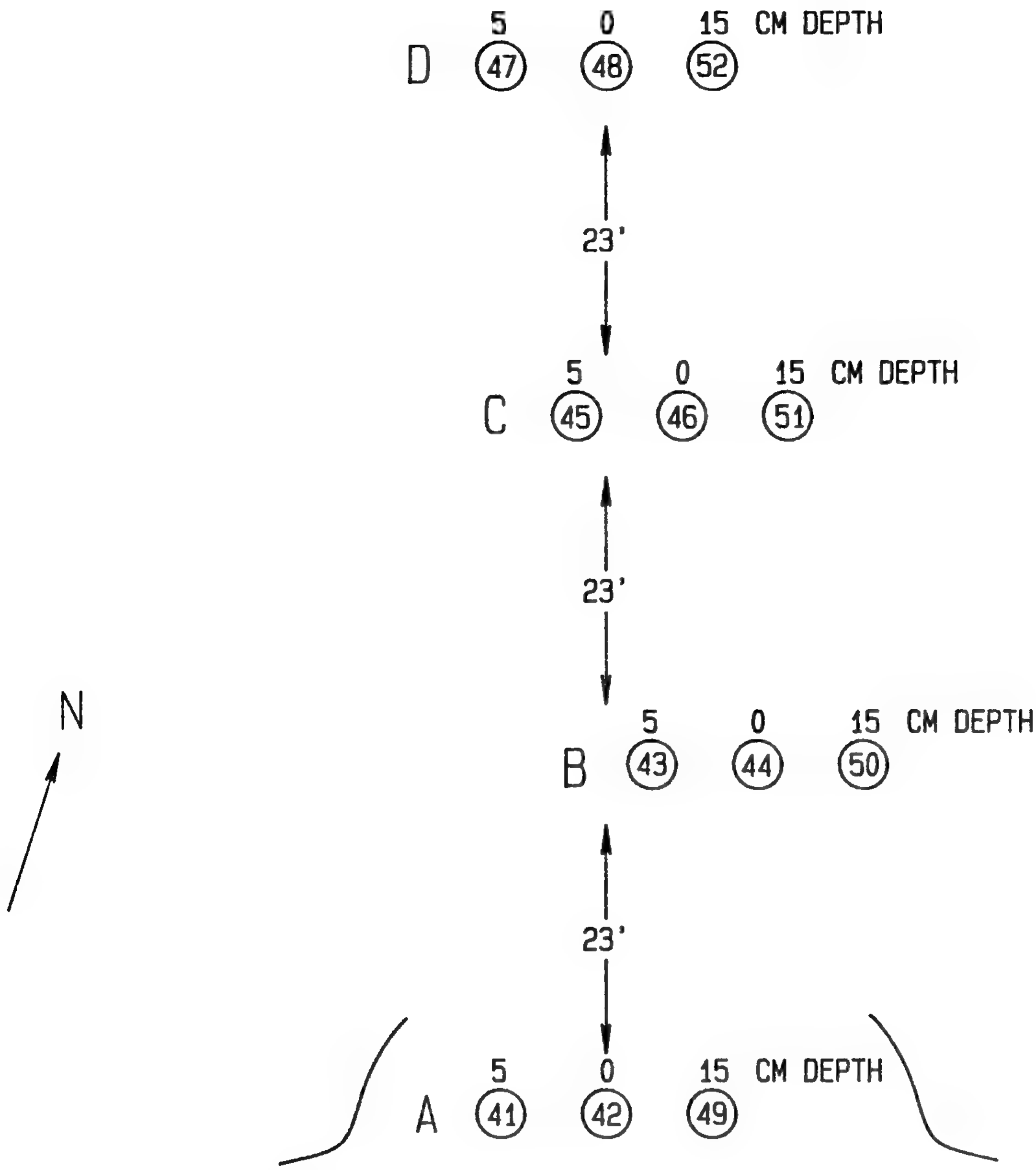



**Figure 5.5: Schematic of Thermocouple Placement for Soil Transect, KRC Primary Site.**
Groups of three probes were placed at 0 cm, 5 cm and 15 cm depths at each of four locations: in the gap at the field/forest edge interface (A), at the open gap/closed canopy interface (B), a short way into the forest interior (C), and a spot deeper in the forest interior (D) that received little direct sunlight.

**Figure 5.6: KRC Primary Site, Photographic View.**

### 5.1.4 Supporting Measurements

**Geophysical and meteorological parameters.**

In order to define and predict the effect of time-dependent factors such as meteorological variables on the thermal characteristics of natural objects, KRC field tests are supported by extensive meteorological observations. Weather data are recorded automatically by an on-site portable weather station, supplemented by visual observations and measurements recorded by field personnel.

The weather and soil parameters recorded automatically by the on-site weather station are listed below. Solar irradiance data is sampled once per minute; all other quantities are sampled once every five minutes.

- o global solar irradiance (0.285 - 2.8 micrometers)
- o longwave incoming radiation (3.0 - 50.0 micrometers)
- o air temperature (0, 1, 2, 3, & 5 meters above ground
- o wind speed (0, 2, & 8 meters above ground)
- o wind direction (8 meters above ground)
- o dew point (degrees Celsius)
- o barometric pressure (millibars)
- o soil temperature profile (0, 0.01, 0.05, 0.1, 0.2, & 0.5 meter depths)

Figure 5.15 shows an excerpt of the hardcopy printout obtained every five minutes from the on-site meteorological station computer.

Field personnel regularly write down observations regarding cloud conditions, cloud cover, atmospheric conditions, precipitation, and related phenomena. These observations are entered on the thermal imagery log sheet.

**Characterization of the forest canopy.**

Measurements of leaf area index and mean tip angle (LAI/MTA) in the forest canopy were obtained using a LICOR LAI-2000 Plant Canopy Analyzer. These measurements are presented and discussed in Appendix A. The measurements of apparent temperatures of scene components obtained with a hand-held spot radiometer are also reported in Appendix A.

Physical samples of vegetation and soil were also taken at the KRC primary site. Typically, these samples would be analyzed, typed, and various physical and radiometric properties determined and included in the site inventory. A large body of such data for the National Experimental Forest sites has already been incorporated to the FED MAC database, and therefore is not duplicated here.

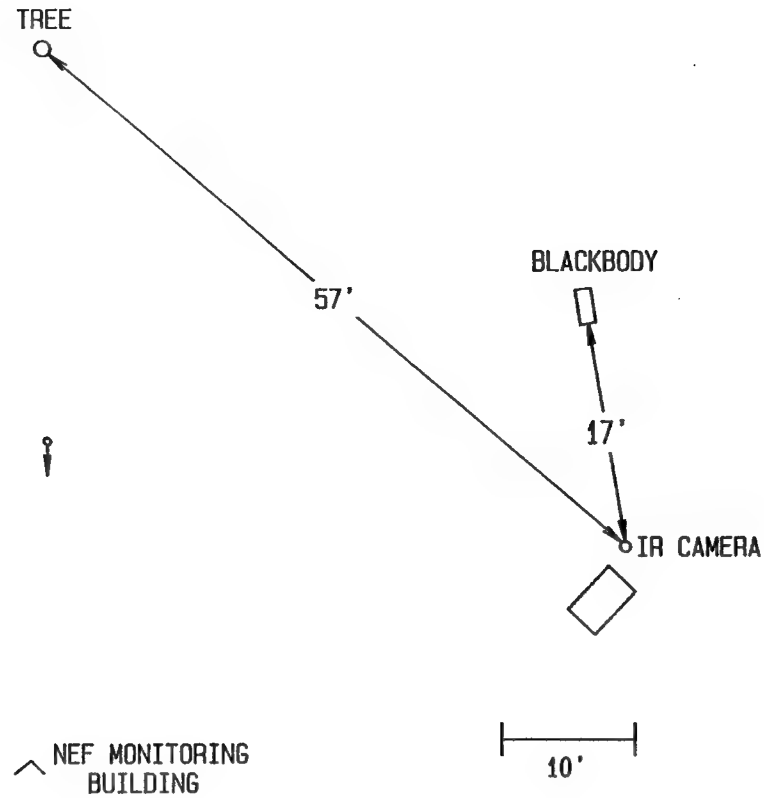



**Figure 5.7: Schematic of KRC Secondary Site, 09 - 11 September, 1990.** Positioning of blackbody, IR camera and monitoring and recording equipment are shown in relation to the study tree and NEF monitoring building.

**Figure 5.8: KRC Secondary Site, Photographic View.**

Table 5.2: **Thermal Imager Specifications.**

| Specification | Inframetrics 610 | | AGEMA 880 |
|---|---|---|---|
| Lens | 1x | 3x | 1x |
| Dynamic range (levels) | 128 | 128 | * |
| Vertical FOV (mrad/deg) | 261(15) | 87(5) | 349(20) |
| Horizontal FOV ("/") | 347(20) | 116(6.7) | 349(20) |
| LWIR band: | | | |
| Spectral bandpass (um) | 8-14 | 8-14 | 8-12 |
| Vert./Horz/ IFOV (mrad) | 2.0 | 0.67 | 175 elt/line |
| NETD | 0.2 | 0.2 | 0.2 |
| NETD-16 frame avg.(°C) | 0.05 | 0.05 | 0.02 |
| MDT (°C) | 0.1 | 0.1 | * |

* Not available.

Figure 5.9: Location A Ground Probes, Soil Temperature Transect.

Figure 5.10: Location B Ground Probes, Soil Temperature Transect.

**Figure 5.11: Location C Ground Probes, Soil Temperature Transect.**

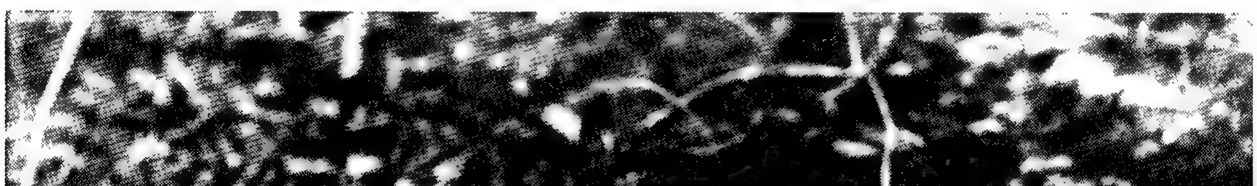


**Figure 5.12: Location D Ground Probes, Soil Temperature Transect.**

### 5.1.5 Thermal Imagery

**Description of Thermal Imagery and Data.**

Thermal imagery is digitized for processing using a PC-based Data Translation frame grabber. Each binary digit frame is supplemented by information from the corresponding frame of blackbody imagery, and converted into a calibrated temperature pixel frame. The temperature value assigned to a pixel is an apparent, or blackbody equivalent temperature, i.e., a blackbody at that temperature would emit the equivalent amount of radiation, in band, that was detected by the thermal imager.

**Thermal Imagery, Primary Site.**

Examples of the background scenes for which thermal imagery was recorded at the KRC primary site are shown in figures on the following pages. The view referred to as "deciduous" consisted of a dense, brushy deciduous bushes and trees along the forest edge just to the west of the gap, and is shown in Figure 5.16. Thermal images of the gap area, itself, are shown in Figures 5.17 and 5.18. A final view, designated "mixed" in reference to the mix of deciduous and coniferous species present along the forest edge just to the east of the gap, is shown in Figure 5.19. Figure 5.20 is an example of the thermal imagery of the blackbody pairs, which was obtained for calibration purposes. Complete listings of image frames and descriptions of file formats are provided in Appendix A.

**Thermal Imagery, Secondary Site**

Examples of thermal imagery of the single poplar recorded at the KRC secondary site are shown in Figures 5.21 and 5.22. Complete listings of image frames and descriptions of file formats are provided in Appendix A.

### 5.1.6 Vegetative Leafy Canopies: Edge Dynamics

The sets of thermal infrared imagery obtained at the KRC Primary Site permitted thermal behaviour of various scene components to be examined and compared across time. Statistics for areas of deciduous vegetation are compared with those for areas of coniferous vegetation in Figures 5.23 through 5.26. These statistics were generated by identifying image sub-regions of coniferous and deciduous vegetation, respectively, in calibrated imagery of "mixed species" along the forest edge, and processing these sub-regions in each image frame. Each figure compares statistics for deciduous vs. coniferous vegetation for a specific twelve-hour period: Figure 5.23 shows relatively low thermal activity overnight, following a heavily overcast day; Figure 5.24 shows results for an overcast day with clouds thinning and abruptly clearing at about 1745, in the afternoon; variable clouds and fog affect overnight conditions shown in Figure 5.25; and Figure 5.26 shows the response of vegetation to conditions of variable clouding, with alternating periods of cloud shadow and of strong sunlight.

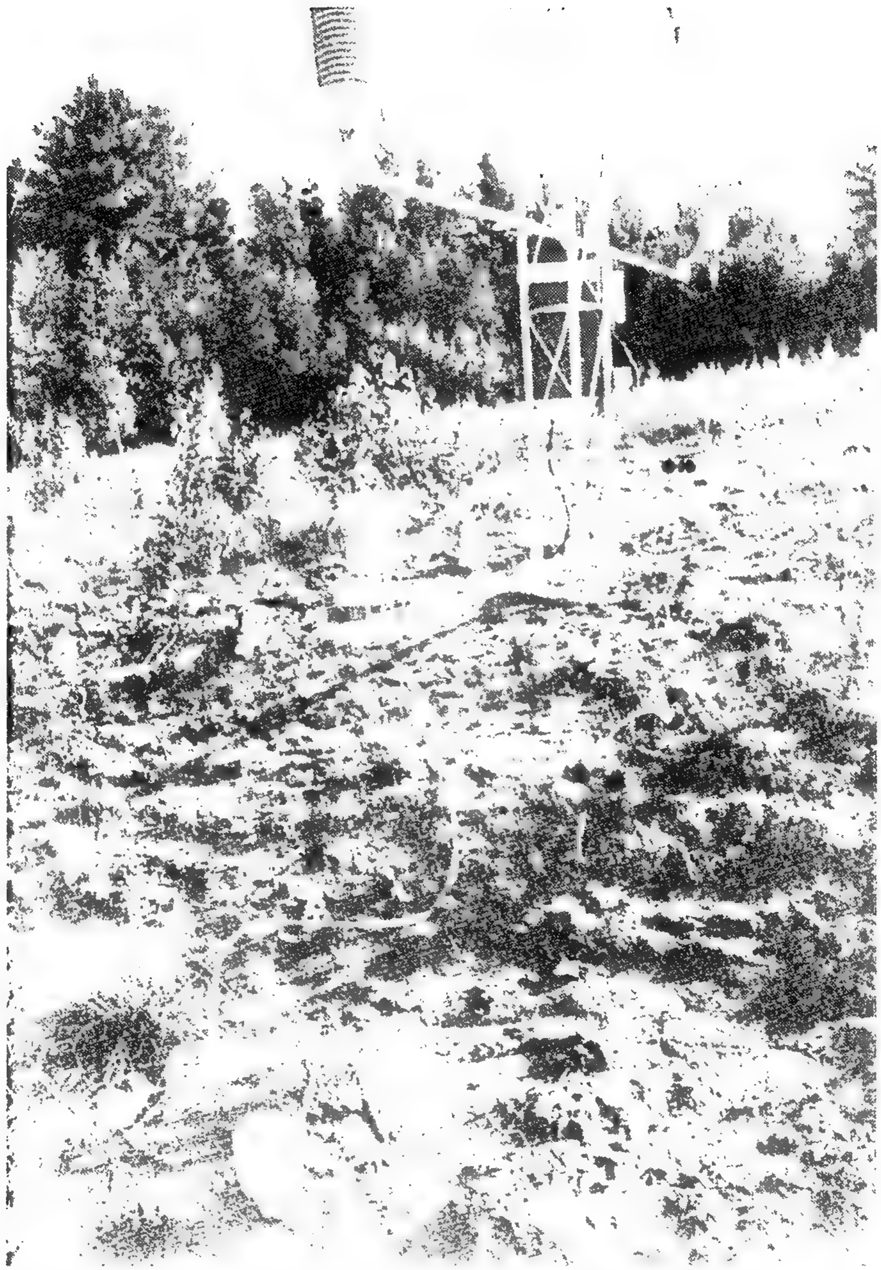


Figure 5.13: Meteorological Tower and Main Ground Probe, in Open Field.

**Figure 5.14: Shielded Thermocouple for Air Temperature, Forest Edge.**

```
==============================================================================
Time: 16:25   Date: 09/10   Sky Temp:   18.532 C
  1 Solar Radiation.....  189.749 W/m^2    2 Longwave IR.........   409.570 W/m^2
  3 LWIR Batt. (1.35v)..    1.345 V        5 Barometric Press.... 1016.270 mB
  7 Doric Temp..........   20.500 C       18 Diffuse Radiation...   156.680 W/m^2
 21 Wind Direction......  169.038 Deg.    22 Wind Speed 8 m.......     1.277 m/sec
 23 Wind Speed 2 m......    0.818 m/sec   24 Wind Speed 0 m.......     0.655 m/sec
 25 Air Temp. 5 m.......   16.900 C       26 Air Temp. 3 m........    16.900 C
 27 Air Temp. 2 m.......   16.800 C       28 Air Temp. 1 m........    17.200 C
 29 Air Temp. 0 m.......   17.200 C       30 Soil Temp. 0 cm.....    18.800 C
 31 Soil Temp. 1 cm.....   18.800 C       32 Soil Temp. 5 cm.....    18.400 C
 33 Soil Temp. 10 cm....   17.900 C       34 Soil Temp. 20 cm....    17.400 C
 35 Soil Temp. 50 cm....   17.900 C       36 Relative Humidity...    95.460 %
 40 Terrain Albedo......   34.400 W/m^2   41 TC 5cm dn  Loc A....    16.900 C
 42 TC 0cm dn  Loc A....   17.800 C       43 TC 5cm dn  Loc B....    15.400 C
 44 TC 0cm dn  Loc B....   16.300 C       45 TC 5cm dn  Loc C....    14.300 C
 46 TC 0cm dn  Loc C....   15.500 C       47 TC 5cm dn  Loc D....    13.800 C
 48 TC 0cm dn  Loc D....   15.300 C       49 TC 15cm dn Loc A....    15.700 C
 50 TC 15cm dn Loc B....   14.800 C       51 TC 15cm dn Loc C....    13.800 C
==============================================================================
Time: 16:30   Date: 09/10   Sky Temp:   18.125 C
  1 Solar Radiation.....  162.819 W/m^2    2 Longwave IR.........   407.287 W/m^2
  3 LWIR Batt. (1.35v)..    1.345 V        5 Barometric Press.... 1016.180 mB
  7 Doric Temp..........   20.600 C       18 Diffuse Radiation...   139.361 W/m^2
 21 Wind Direction......  178.470 Deg.    22 Wind Speed 8 m.......     1.111 m/sec
 23 Wind Speed 2 m......    0.879 m/sec   24 Wind Speed 0 m.......     0.065 m/sec
 25 Air Temp. 5 m.......   17.100 C       26 Air Temp. 3 m........    17.100 C
 27 Air Temp. 2 m.......   17.100 C       28 Air Temp. 1 m........    17.300 C
 29 Air Temp. 0 m.......   17.300 C       30 Soil Temp. 0 cm.....    19.100 C
 31 Soil Temp. 1 cm.....   19.000 C       32 Soil Temp. 5 cm.....    18.500 C
 33 Soil Temp. 10 cm....   17.900 C       34 Soil Temp. 20 cm....    17.400 C
 35 Soil Temp. 50 cm....   17.900 C       36 Relative Humidity...    94.475 %
 40 Terrain Albedo......   27.800 W/m^2   41 TC 5cm dn  Loc A....    16.900 C
 42 TC 0cm dn  Loc A....   18.000 C       43 TC 5cm dn  Loc B....    15.400 C
 44 TC 0cm dn  Loc B....   16.400 C       45 TC 5cm dn  Loc C....    14.300 C
 46 TC 0cm dn  Loc C....   15.600 C       47 TC 5cm dn  Loc D....    13.800 C
 48 TC 0cm dn  Loc D....   15.400 C       49 TC 15cm dn Loc A....    15.600 C
 50 TC 15cm dn Loc B....   14.800 C       51 TC 15cm dn Loc C....    13.800 C
==============================================================================
```

**Figure 5.15: KRC Meteorological Station Hardcopy Printout, Example.**

Statistics of variation and second-order statistics were also calculated for deciduous and coniferous image sub-regions, in order to compare the distributions of apparent temperature values across time and under various physical conditions. Figures 5.27, 5.28, and 5.29 summarize the standard deviation, skew, and kurtosis, respectively, for deciduous vs. coniferous vegetation. The strongest variations in skewness and kurtosis occur during periods of minimal overall variation in temperature, and thus are probably of little information value. The most significant portions of these graphs are along the rightmost edges, the time period from 0700 to 1300 on 11 September, 1990. Variable meteorological conditions during this period contributed to higher and more variable temperatures, as indicated by the relatively large standard deviations in Figure 5.27; skewness and kurtosis are consistently nominal during this same time period, suggesting a very normal temperature distribution for vegetation.

Thermal infrared imagery of the gap in the forest edge provided an opportunity to analyze several different scene components simultaneously. As well as showing patches of (predominantly deciduous) vegetation along the edge and patches of vegetation recessed within the shaded interior of the forest, these images also clearly show trunks of both live and dead trees. Statistics were calculated for image sub-regions and are shown in the following set of figures: Figure 5.30 shows apparent temperature range and average for vegetation along the forest edge adjacent to the gap; Figure 5.31 for vegetation within the gap, in the forest interior; Figure 5.32 for the trunk of a live spruce tree visible in the gap; and Figure 5.33 for the trunk of a dead spruce tree visible in the gap. Descriptions of statistics files for these scene components are also given in Appendix A.

Contrasts in the thermal behaviour of these diverse scene elements are more clearly evident in the comparisons of averages shown in Figures 5.34, 5.35 and 5.36. In Figure 5.36, in particular, it may be seen that both transient and overall responses to increased solar loading (on the rightmost segment of graph) are very different for live vs. dead vegetation, and for leafy vegetation vs. the tree trunk.

### 5.1.7 Soil Temperature Transect into Forest Edge

The soil temperature transect recorded data at various soil depths and locations, at the KRC primary site during the FED MAC 1990 experiment. Data was collected from sets of thermocouples set into the soil at three different depths - 0 cm (soil surface), 5 cm, and 15 cm - at each of four locations - labelled A, B, C, and D - in the forest edge, and recorded at five minute intervals. A schematic of the thermocouple probe locations was given in Figure 5.5, earlier in this report.

Figures 5.37 through 5.40 graphically depict the soil temperature data recorded at all depths (0, 5, and 15 cm.) at locations A, B, C, or D, respectively, across time. Figures 5.41, 5.42, and 5.43, on the following pages, graphically compare readings from probes set at a specific depth at all locations, across time.

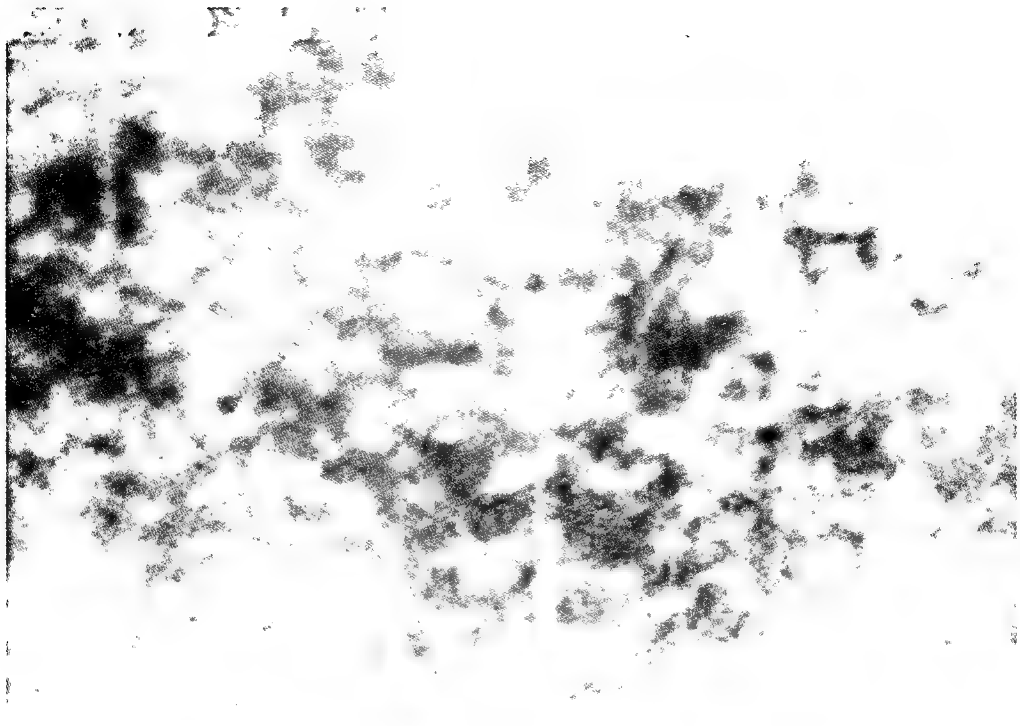


**Figure 5.16: Infrared Imagery of Deciduous Vegetation at Forest Edge, West Side of Gap, Inframetrics 610, 3X Lens, $8 - 14\mu$m.**

**Figure 5.17: Infrared Imagery of Forest Gap** Inframetrics 610, 1X Lens, $8 - 14\mu$m.

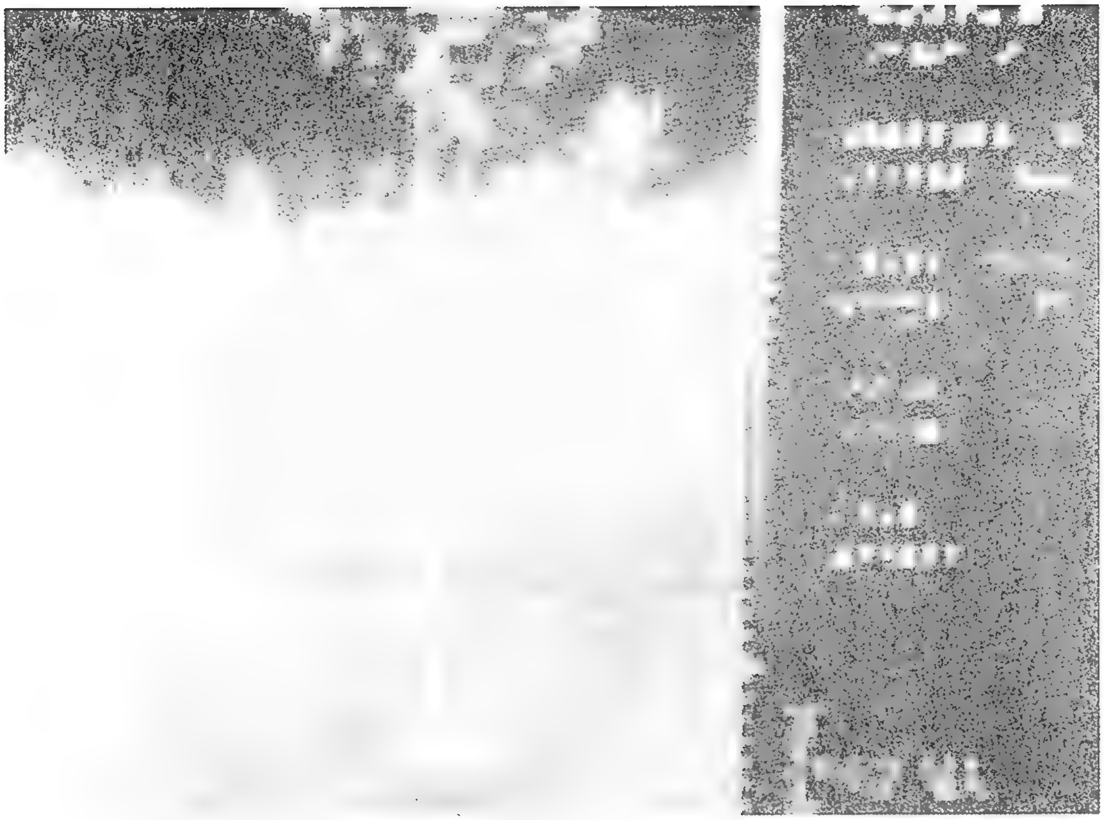


**Figure 5.21: Infrared Imagery of Single Tree, Trunk and Lower Branches** from AGEMA 880, $8 - 14\mu$m.

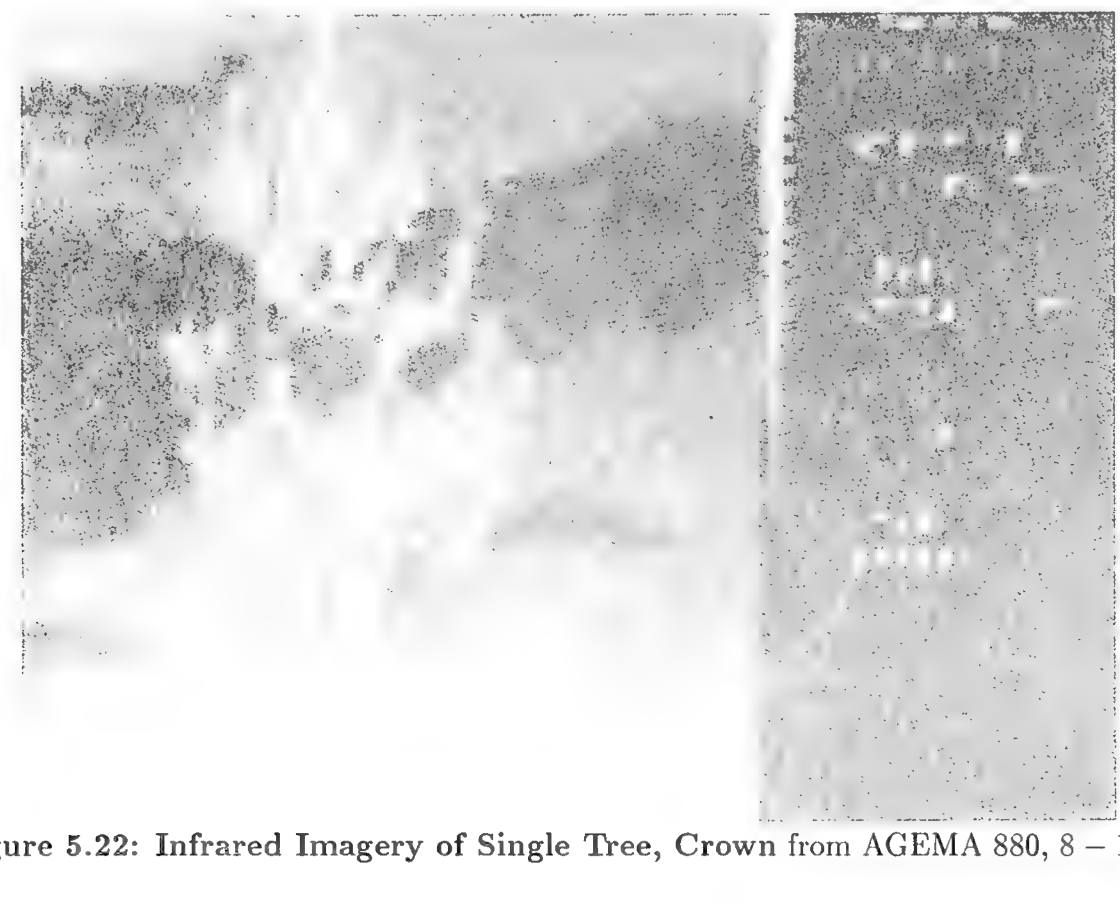
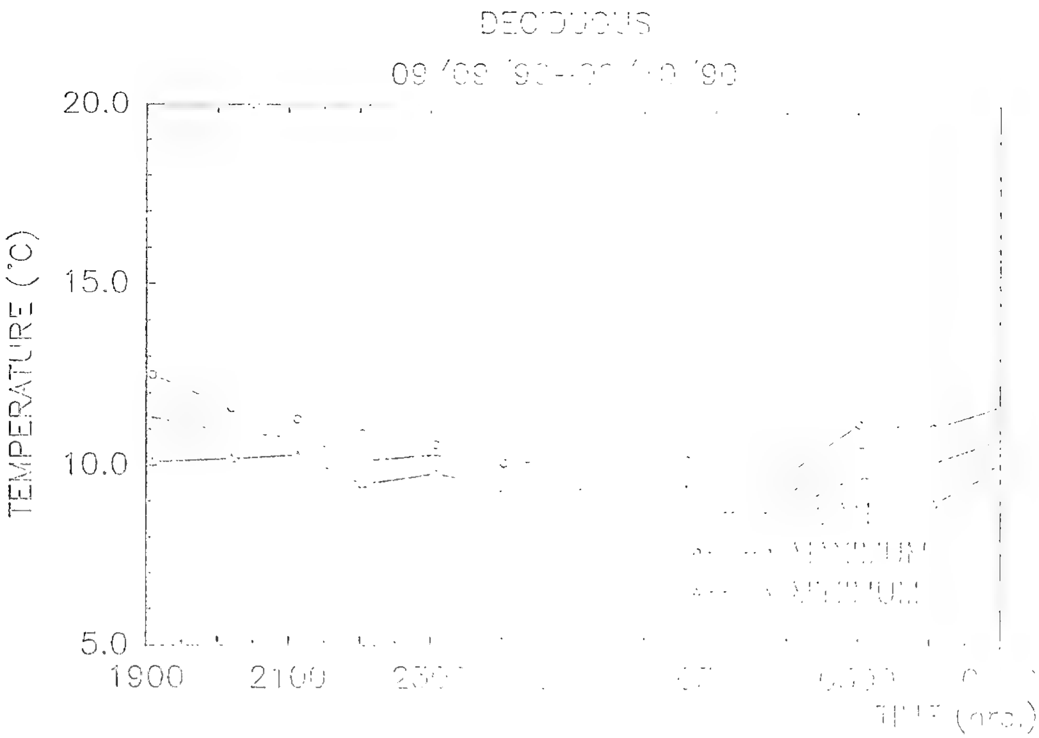


**Figure 5.22: Infrared Imagery of Single Tree, Crown** from AGEMA 880, $8 - 14\mu$m.



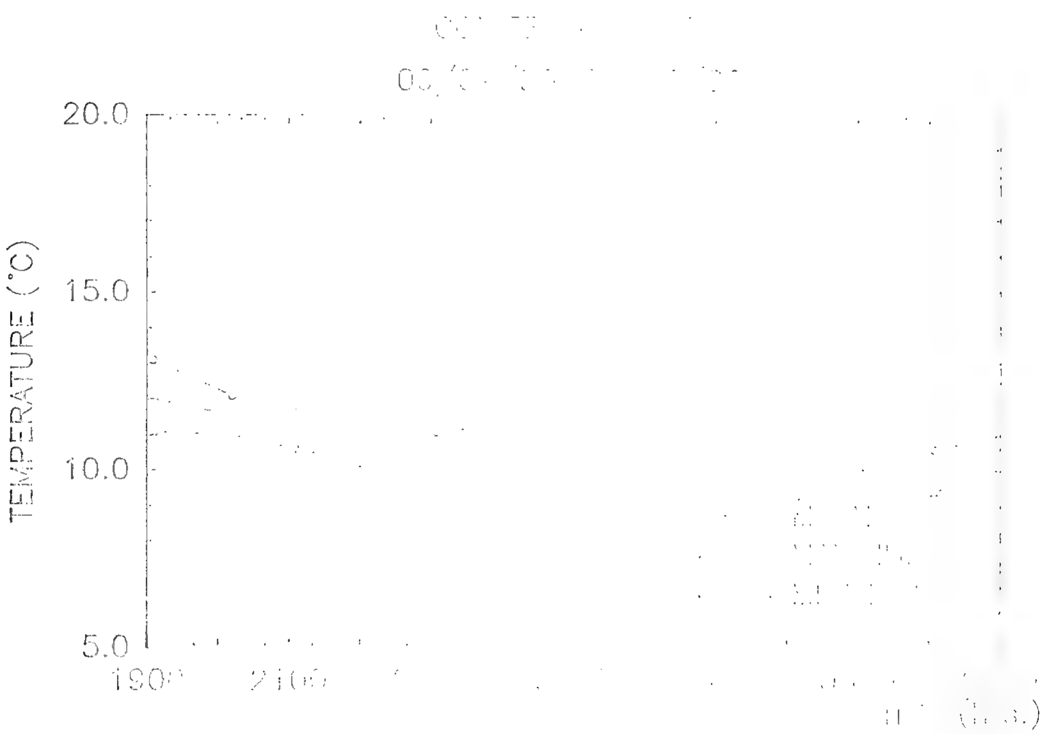




Figure 5.2 [illegible]
Shown Across Time [illegible]
0700 hours on [illegible]

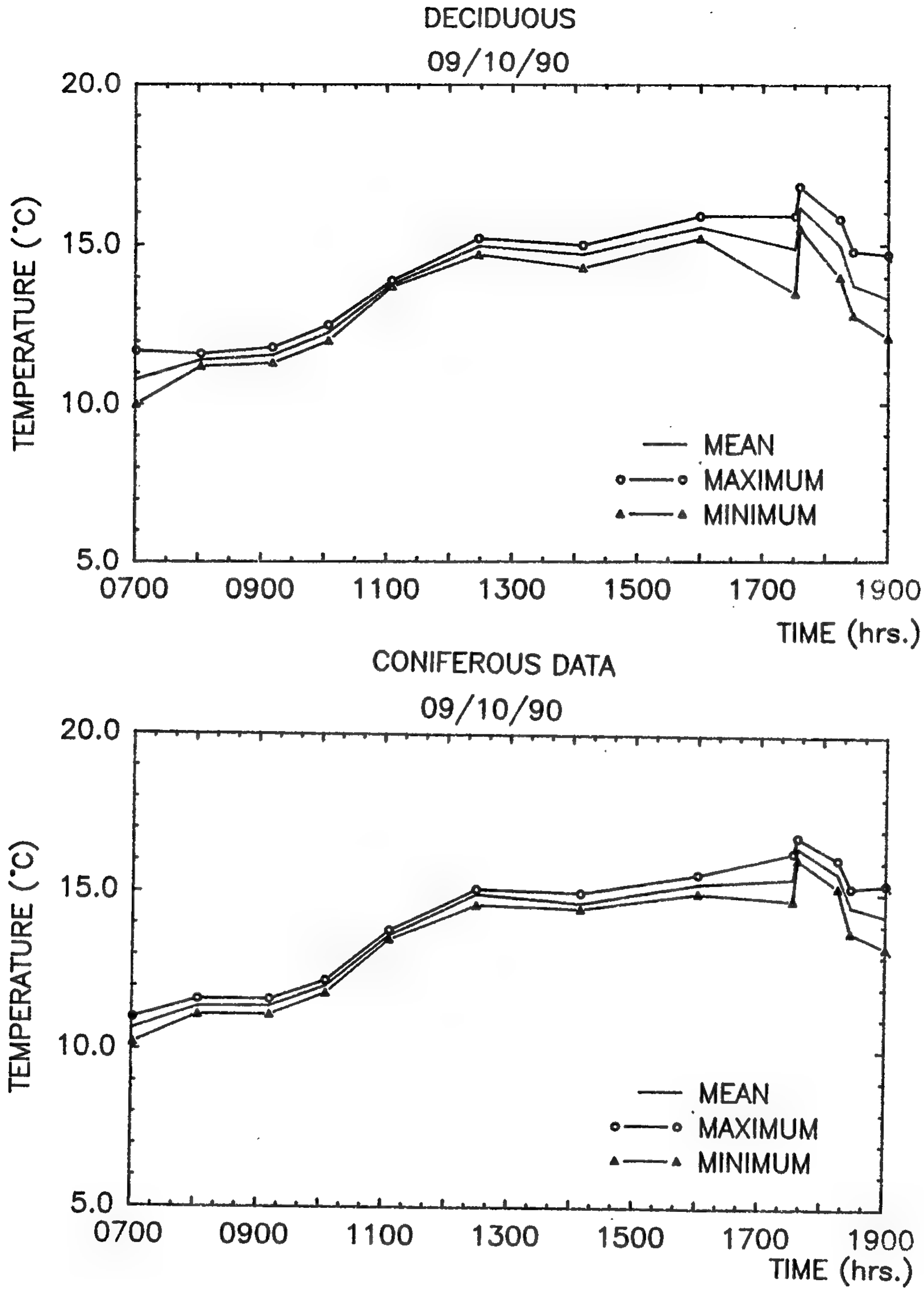



**Figure 5.24: Descriptive Statistics for Deciduous and Coniferous Vegetation.** Shown Across Time for daytime period from 0700 hours through 1900 hours on 10 September, 1990.

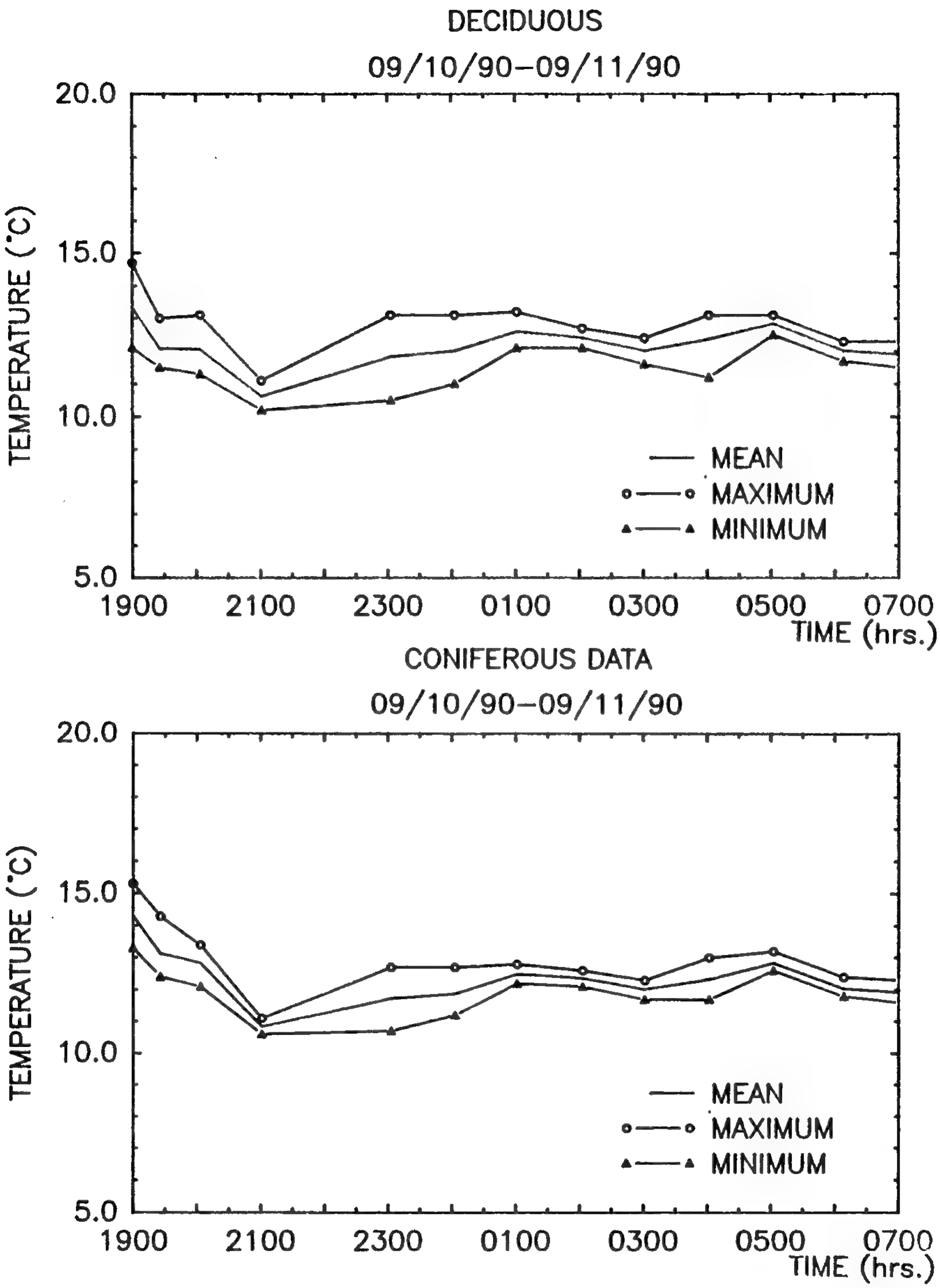
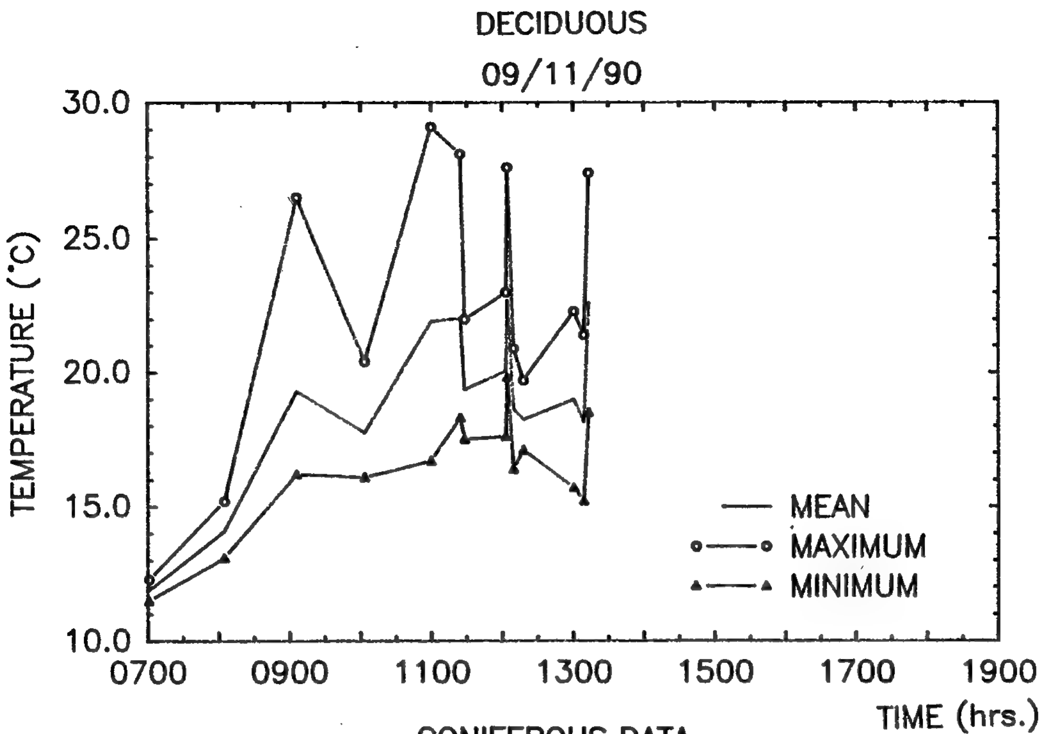



**Figure 5.25: Descriptive Statistics for Deciduous and Coniferous Vegetation** Shown Across Time for overnight period from 1900 hours on 10 September, 1990 through 0700 hours on 11 September, 1990.



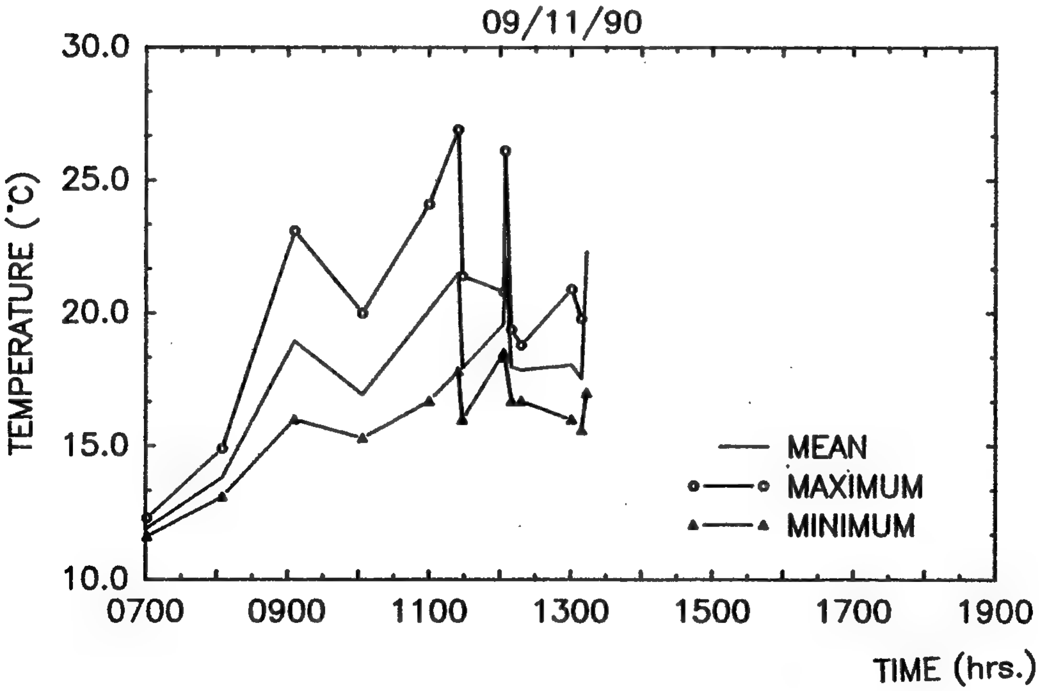




**Figure 5.26: Descriptive Statistics for Deciduous and Coniferous Vegetation** Shown Across Time for daytime period from 0700 hours through 1330 hours on 11 September, 1990.

### 5.1.8 Single, Isolated Tree Thermal Response

Videotapes of all thermal infrared imagery recorded at the KRC secondary site have been provided to Sparta, Inc., to support their individual tree thermal response study and modeling efforts, and also to the U.S. Army Communications and Electronics Command Center for Night Vision and Electro-Optics (C2NVEO). Copies of computer files of supporting meteorological and physical data, and of digitized thermal imagery have also been provided to Sparta, Inc.

Descriptive statistics for the apparent temperatures of the single tree trunk, leaf clusters, and for adjacent ground surfaces were generated using OS7 software (described in the section on scene metrics/enhancement of image processing capabilities, below.) These statistics and related data are detailed in the report contained in Appendix B.

## 5.2 Information data base

The Standard Scenes database was organized to make it compatible with modeling community needs, and was made available to the modeling community. The content and present format of data contained in the Standard Scenes database are described in Appendix C.

The experience gained from establishing the Standard Scenes database provides useful insights to help develop a database structure that will accommodate the large amount of information collected during measurement and characterization activity.

## 5.3 Modeling and simulation

### 5.3.1 Enhancement of Image Processing Capabilities

KRC has thermal digital image processing software to efficiently analyze calibrated thermal imagery. Based on the Silicon Graphics Model 3130 and 4D Series Graphics Workstations with UNIX system, the "OS7" software permits menu-driven processing of individual image frames, and database building from frame sequence statistics and image metric calculations. OS7 is written in FORTRAN, and contains no machine-specific commands nor proprietary subroutines from sources outside KRC; it is therefore a highly adaptable and easily portable program.

The OS7 menu features useful for analysis include image file selection, choice of a variety of input file format specifications, range and offset display selection, choice of 4 display scales (standard gray scale, inverted gray, green, and pseudo-color), and pixel interrogation. In addition, the menu provides for creation of rectangular or polygonal templates defining image sub-regions. Statistics are calculated for these sub-regions, and can be directed to an output disk file for storage.

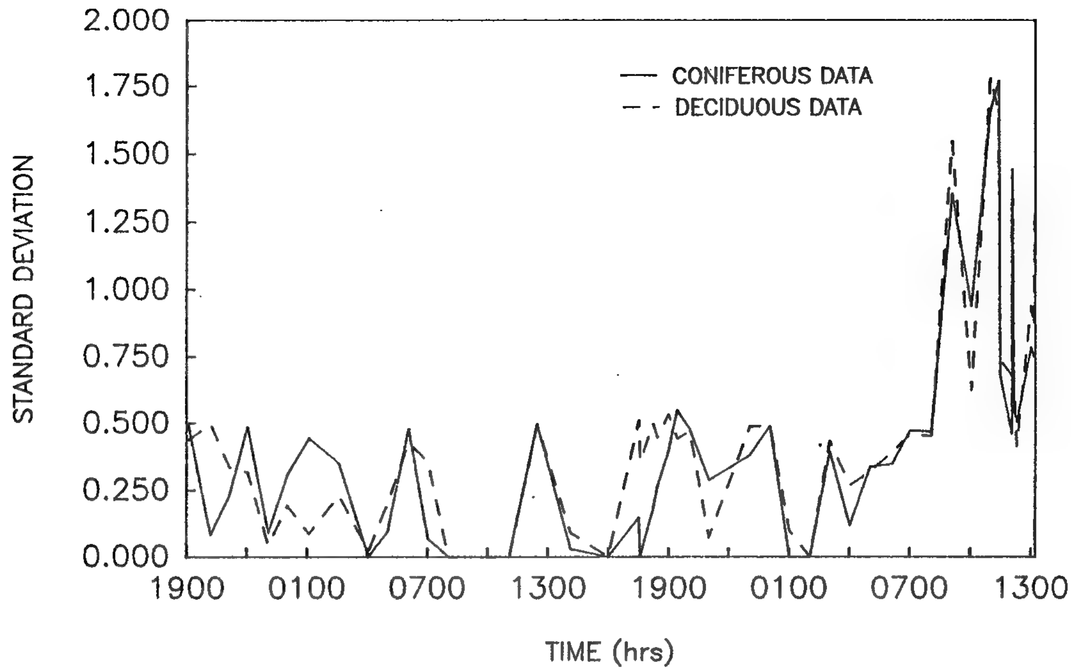



**Figure 5.27: Standard Deviation for Deciduous vs. Coniferous Vegetation at Forest Edge.**

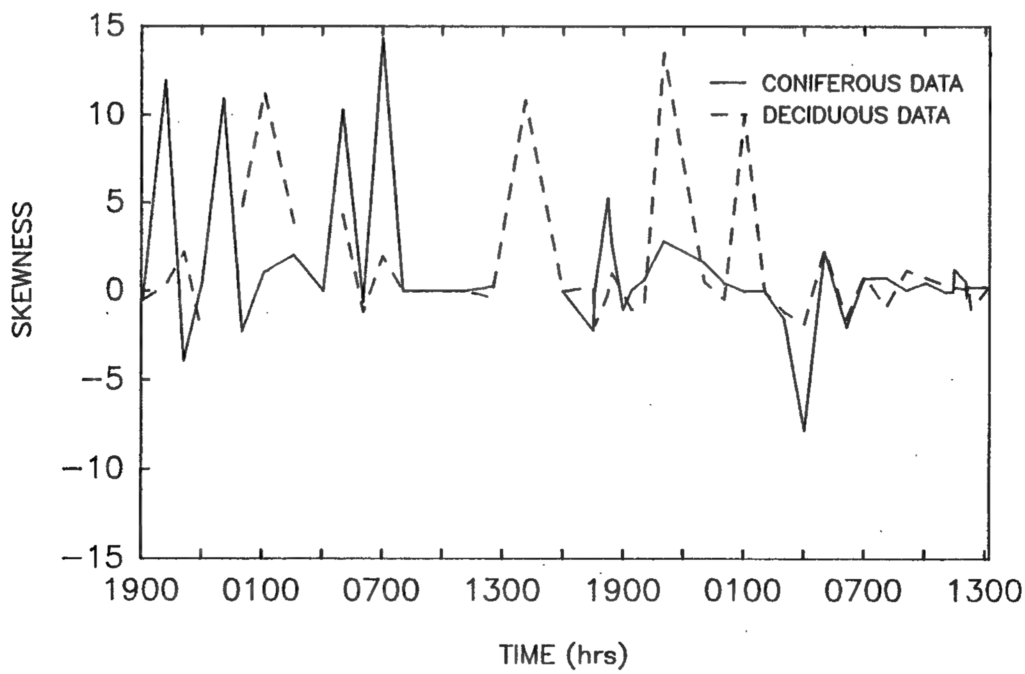



**Figure 5.28: Second-Order Statistics for Deciduous vs. Coniferous Vegetation at Forest Edge: Skewness.**

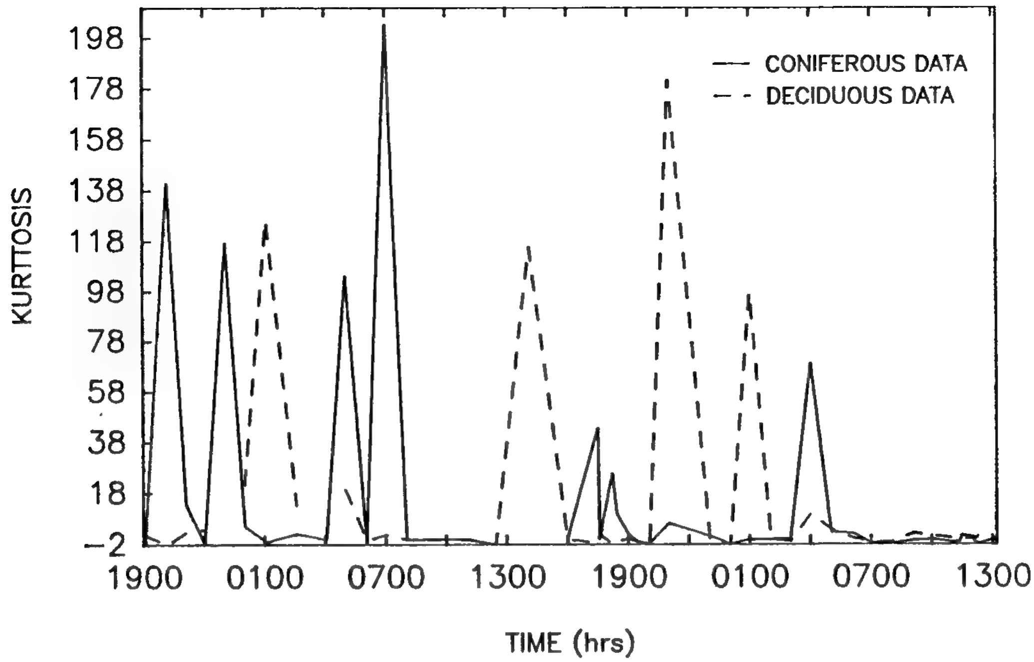



**Figure 5.29: Second-Order Statistics for Deciduous vs. Coniferous Vegetation at Forest Edge: Kurtosis.**

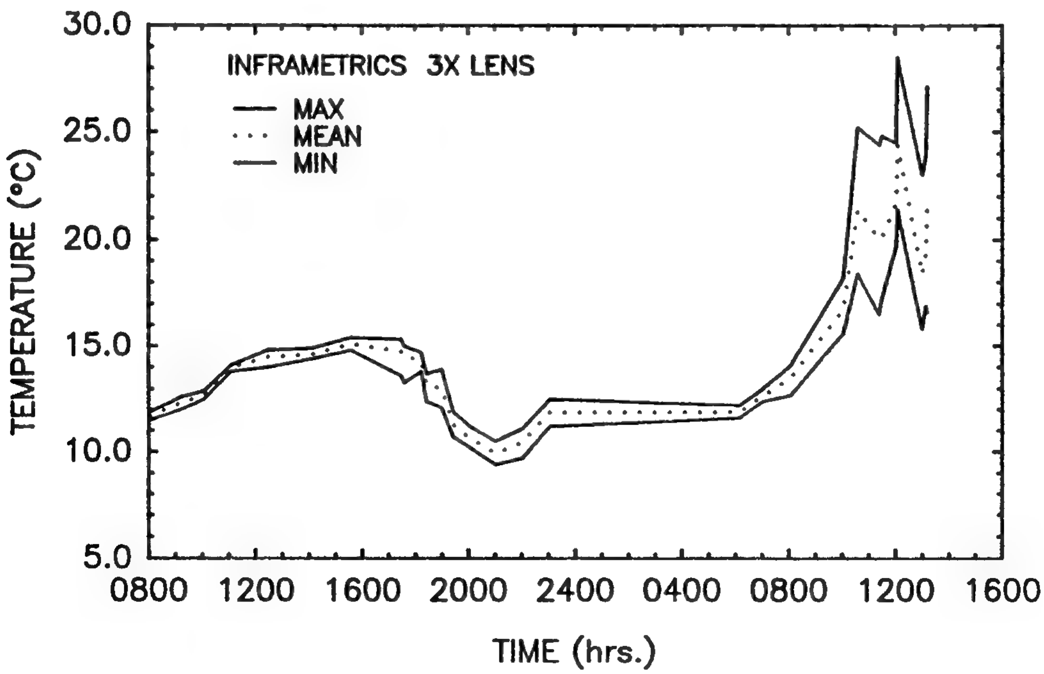



**Figure 5.30: Maximum, Minimum, and Average Values of Apparent Temperature of Vegetation Along Forest Edge.**

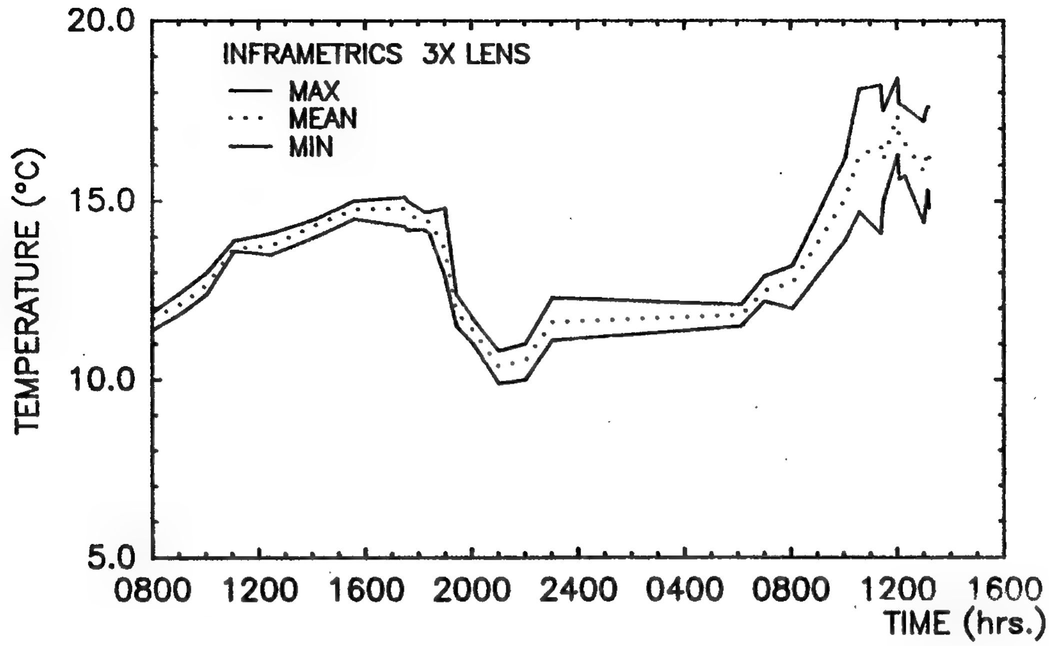



**Figure 5.31: Maximum, Minimum, and Average Values of Apparent Temperature of Vegetation Within Forest Interior, in Gap Area.**

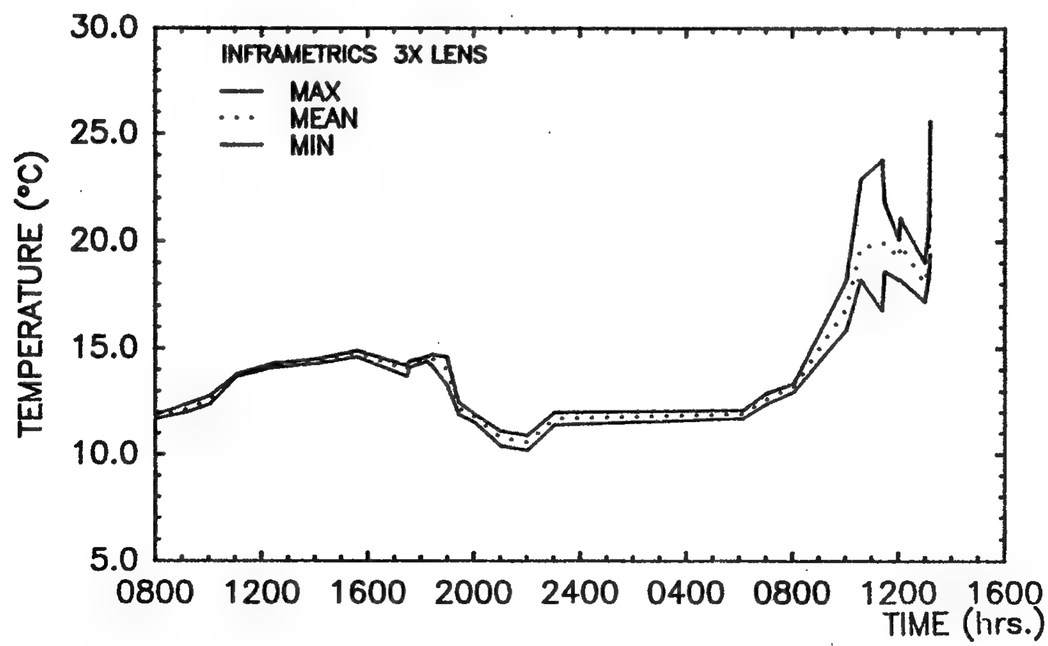



**Figure 5.32: Maximum, Minimum, and Average Values of Apparent Temperature of Live Tree Trunk, in Gap Area.**

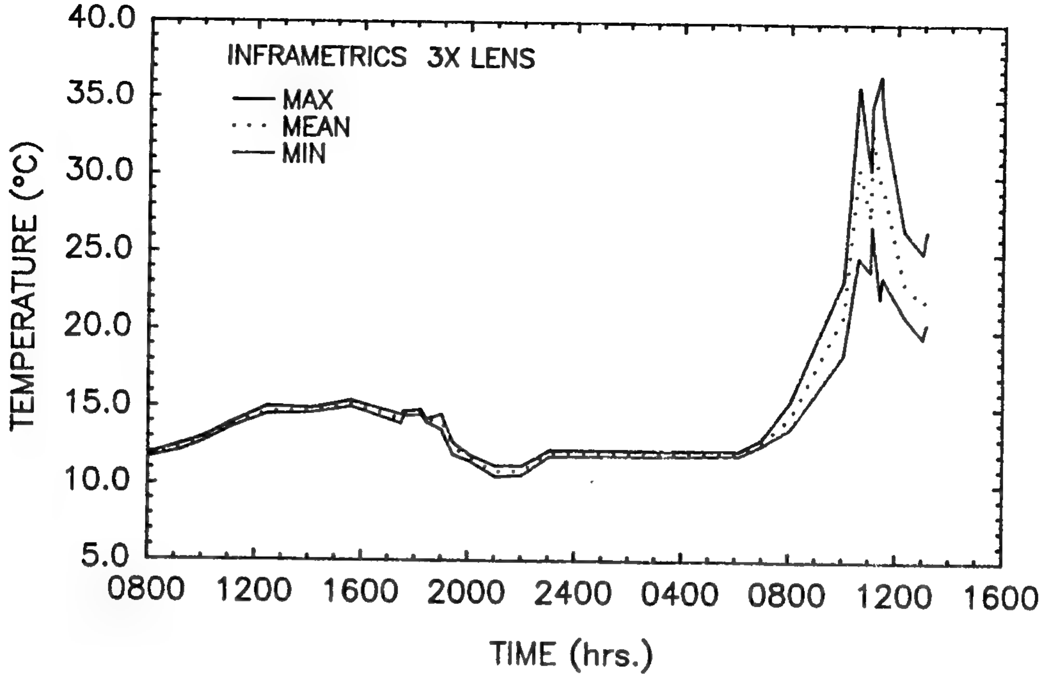



**Figure 5.33: Maximum, Minimum, and Average Values of Apparent Temperature of Dead Tree Trunk, in Gap Area.**

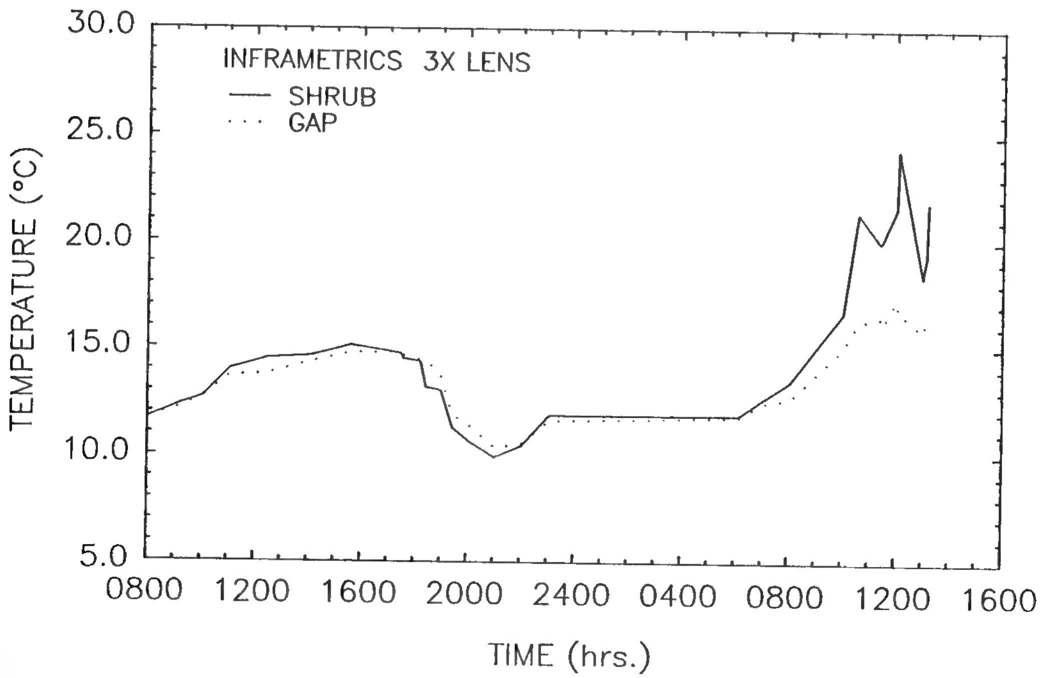



**Figure 5.34: Comparison of Average Apparent Temperatures of Selected Scene Components, Across Time.** Leafy subregions along forest edge ("SHRUB"), and within forest gap ("GAP").

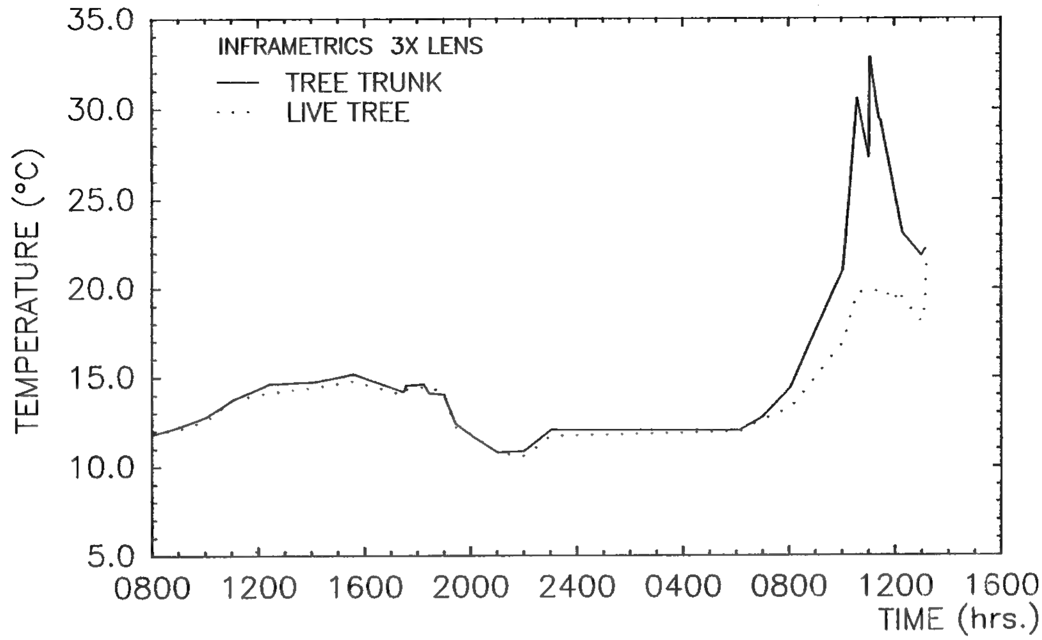



**Figure 5.35: Comparison of Average Apparent Temperatures of Selected Scene Components, Across Time.** Trunk of a live tree ("LIVE TREE"), and a standing dead tree ("TREE TRUNK").

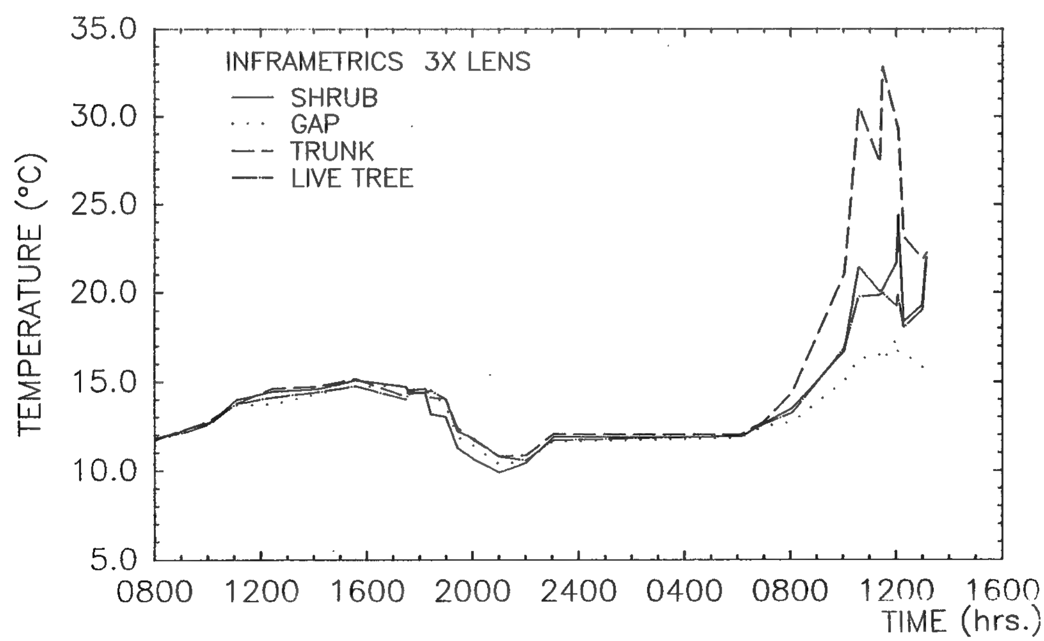



**Figure 5.36: Comparison of Average Apparent Temperatures of Selected Scene Components, Across Time.** Leafy subregions along forest edge ("SHRUB") and within forest gap ("GAP"), trunk of a live tree ("LIVE TREE"), and a standing dead tree ("TREE TRUNK").

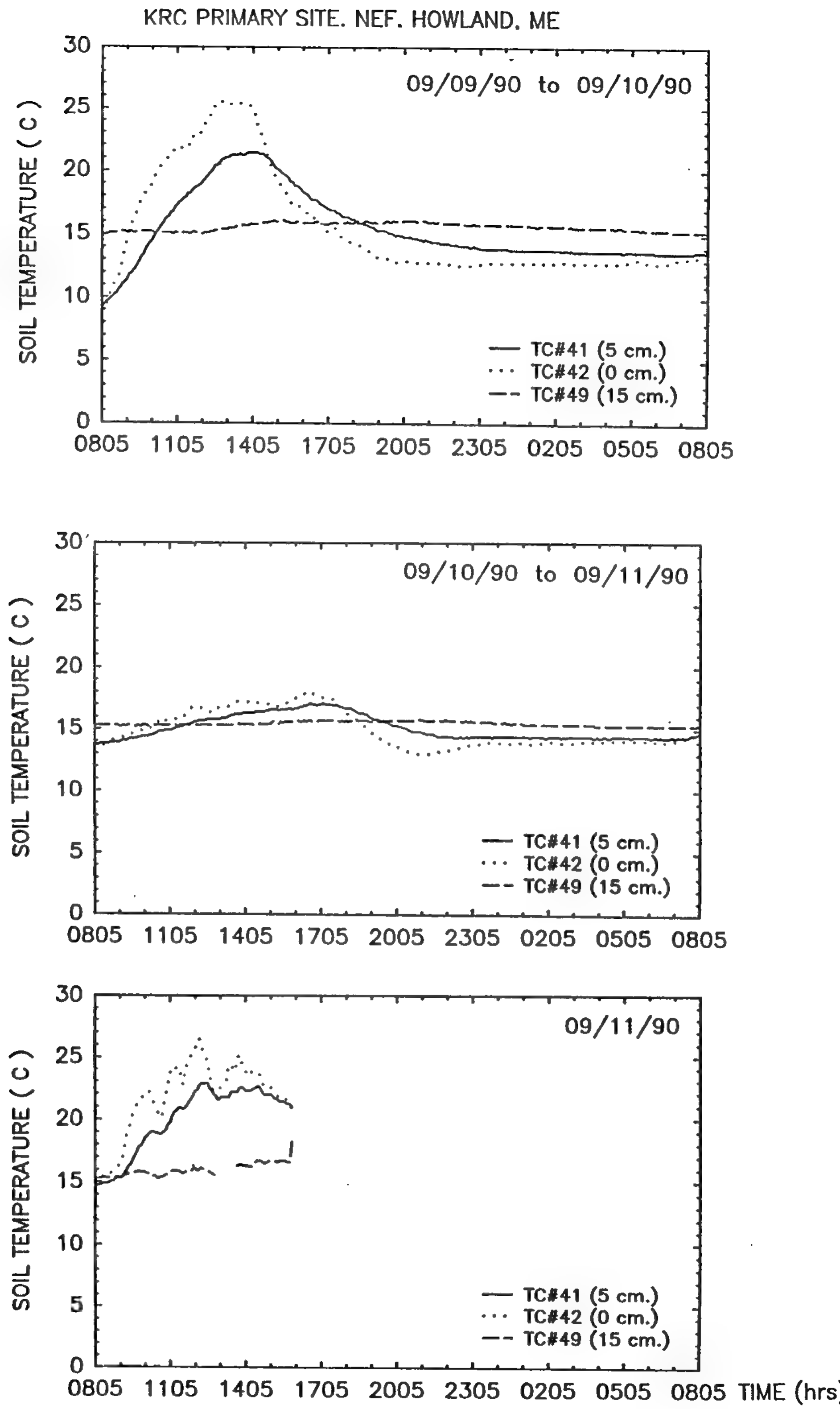



**Figure 5.37: Soil Temperatures (°C) at 0, 5, and 15 cm, Location A.**

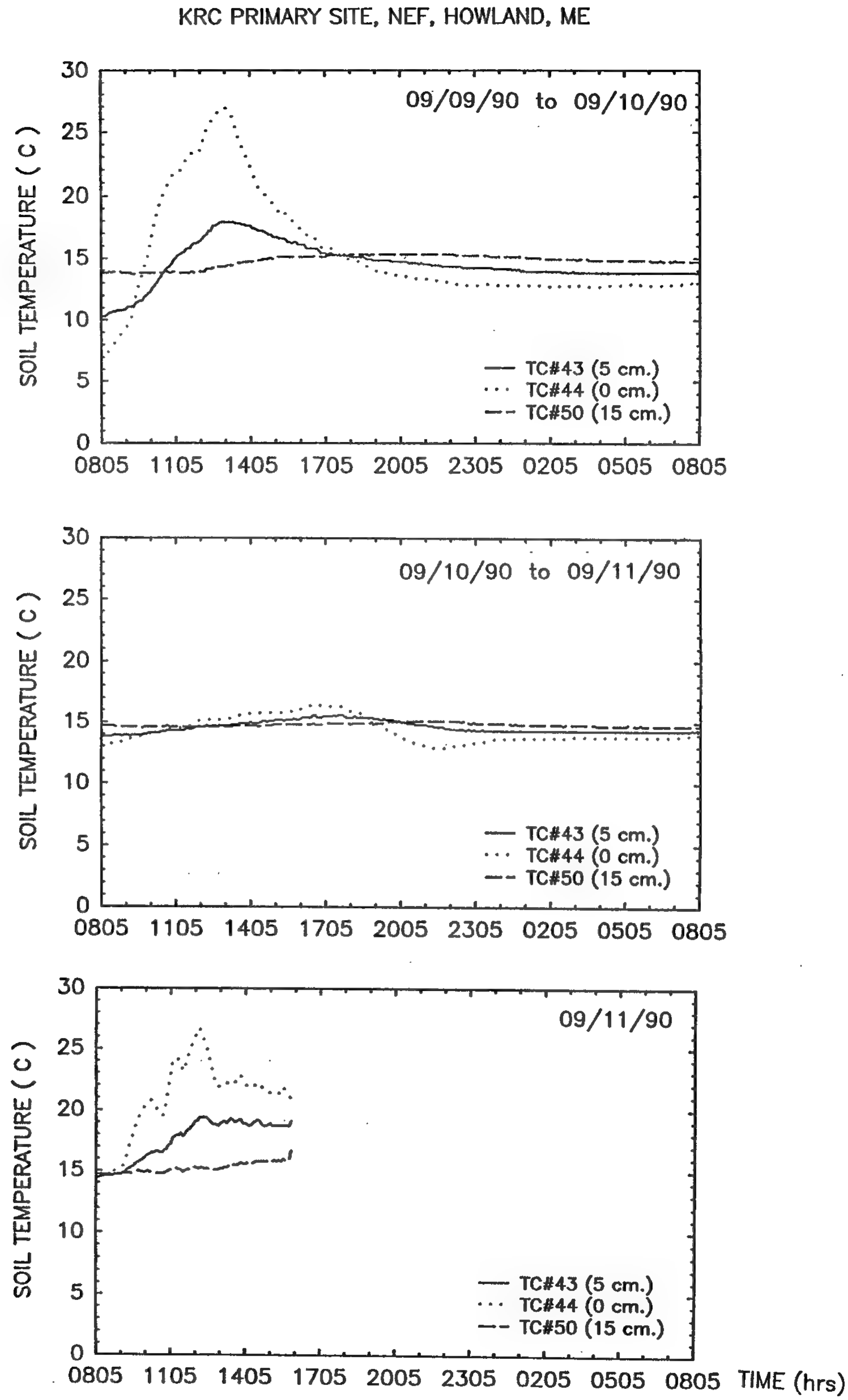



Figure 5.38: Soil Temperatures (°C) at 0, 5, and 15 cm, Location B.

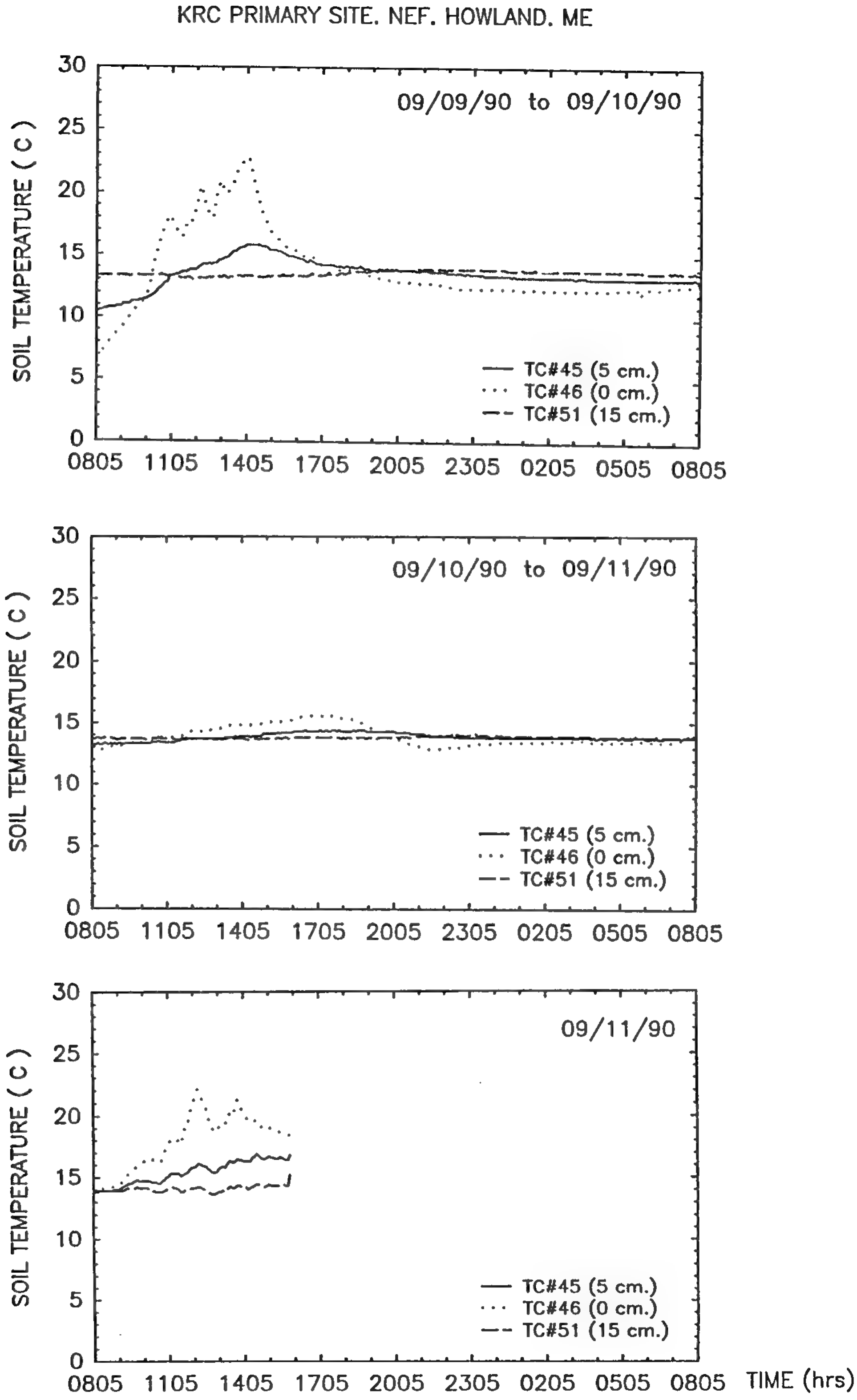



**Figure 5.39: Soil Temperatures (°C) at 0, 5, and 15 cm, Location C.**

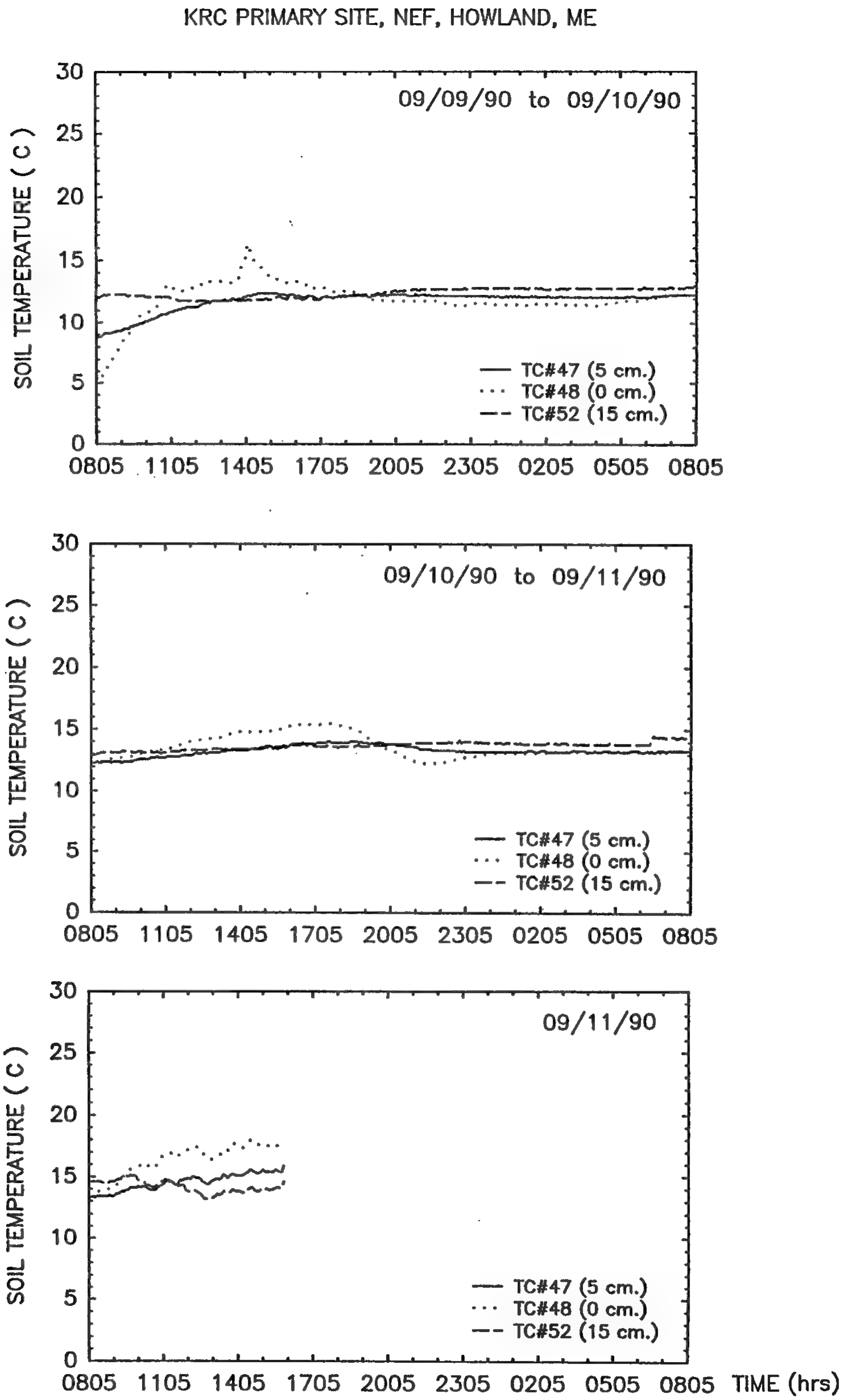



**Figure 5.40: Soil Temperatures (°C) at 0, 5, and 15 cm, Location D.**

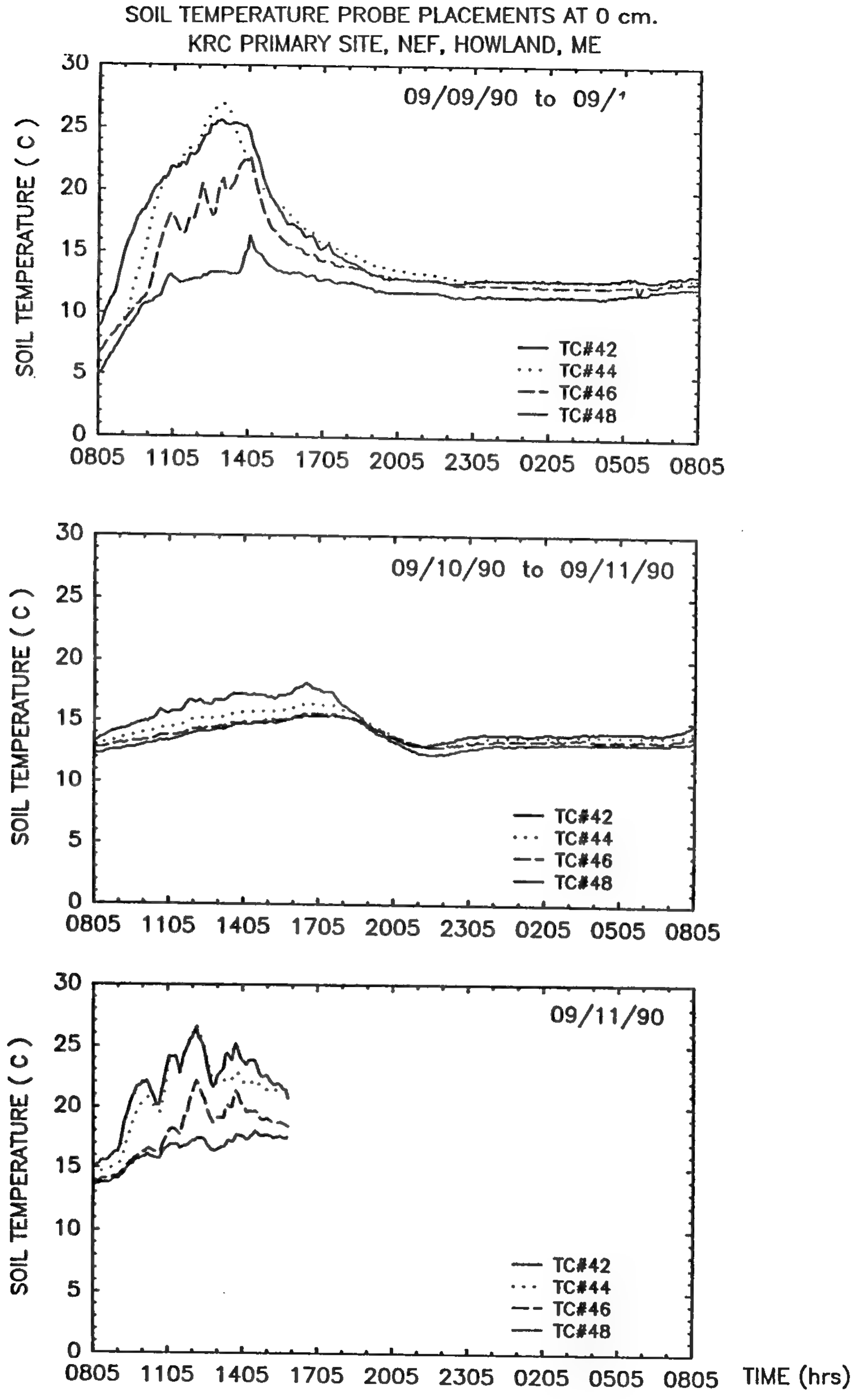



Figure 5.41: Soil Temperatures (°C) at 0 cm (Surface) Across Soil Transect.

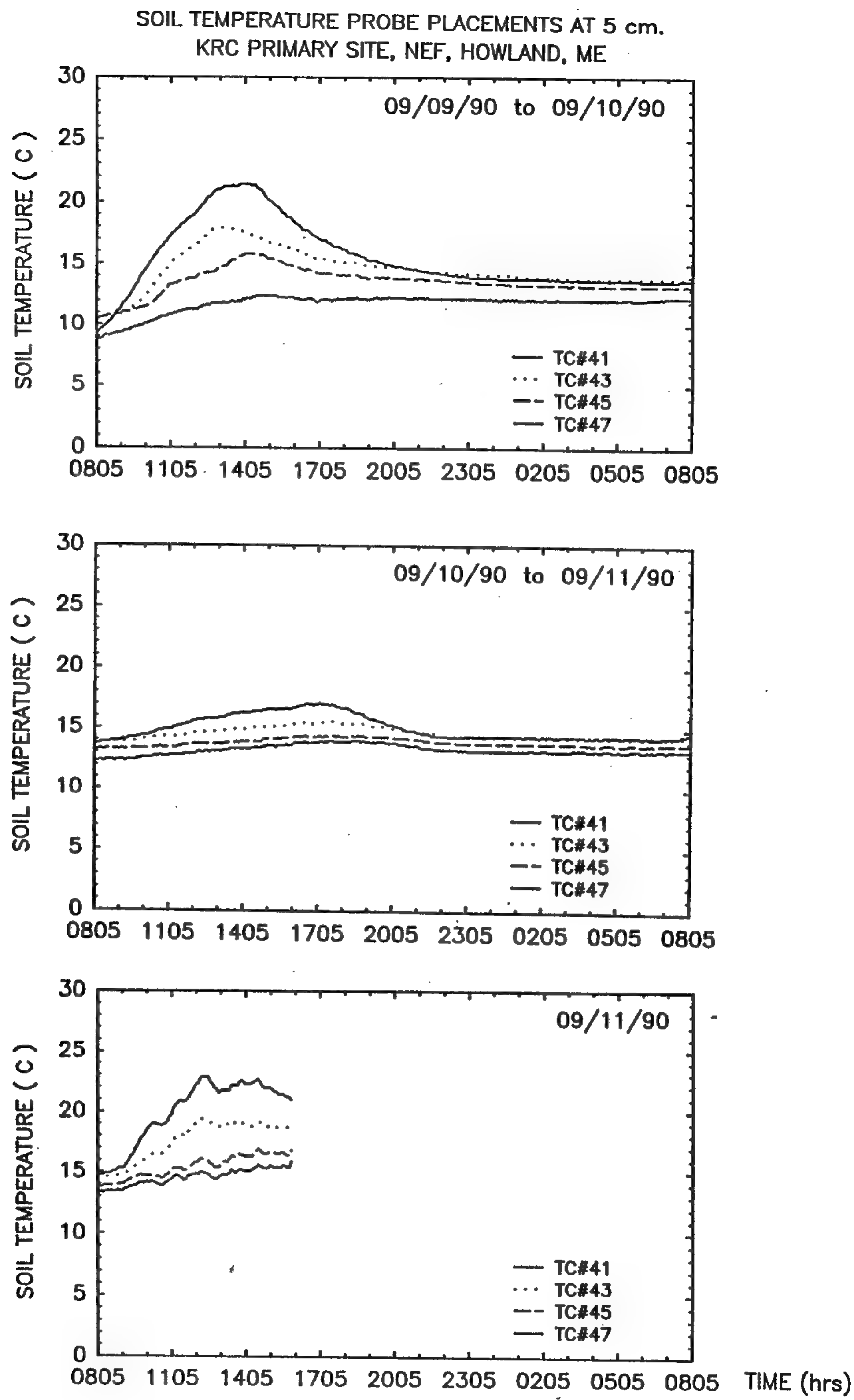



**Figure 5.42: Soil Temperatures (°C) at 5 cm Depth, Across Soil Transect.**

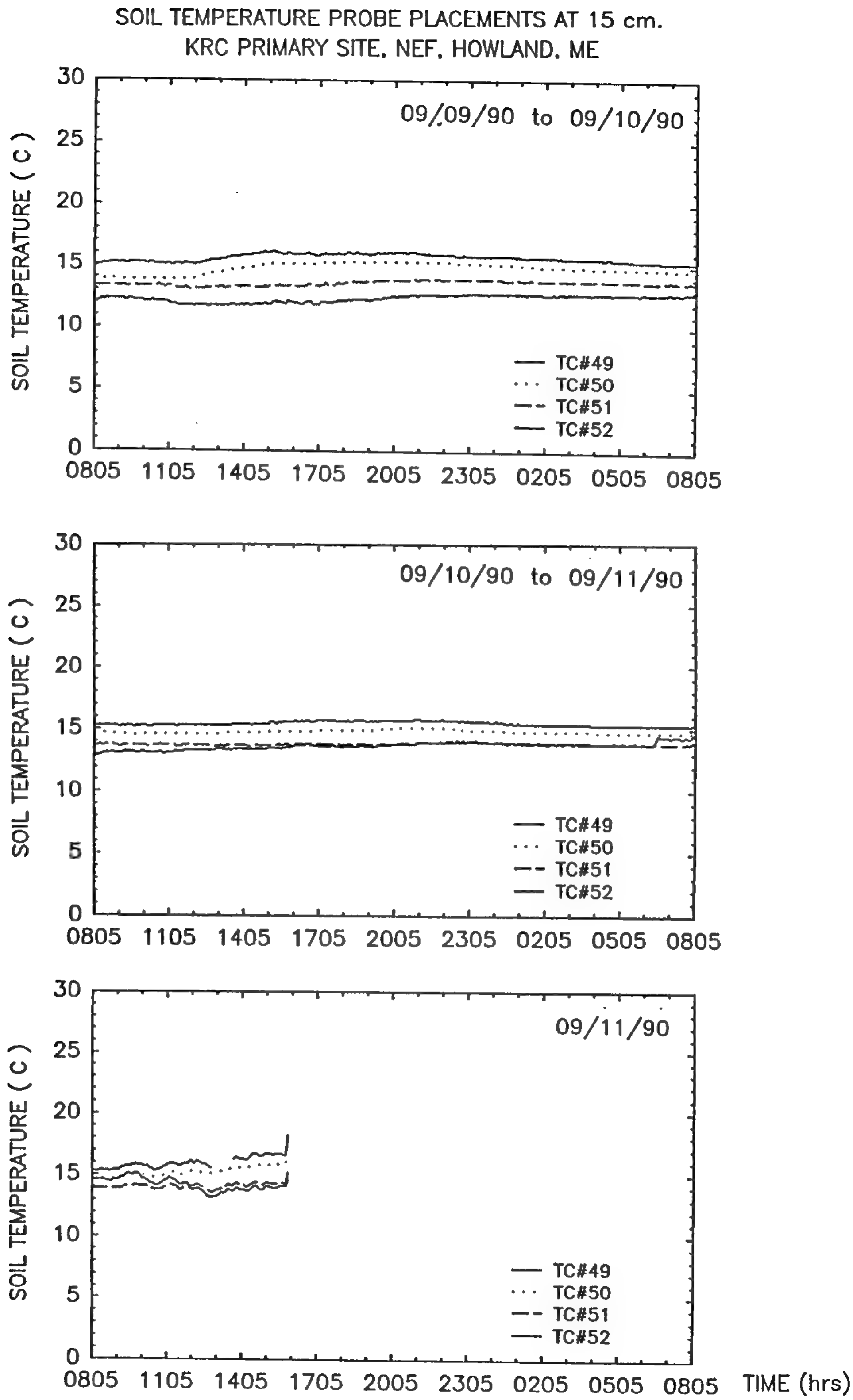



Figure 5.43: Soil Temperatures (°C) at 15 cm Depth, Across Soil Transect.

The menu has recently been augmented to include on-screen image processing capabilities: pixel averaging, on-screen frame reduction, on-screen mapping of pixel values from a gray scale (0-255) to a temperature scale specified by the user, and the option to save the reduced or temperature-converted version of the image frame to its own file. Figure 5.44 shows the OS7 menu display with this new feature, the image processing option, opened and ready for use.

The handling of image sub-regions has also been enhanced by the ability to store the individual pixel values in the sub-region to a separate file, and by an expanded repertoire of values that can be calculated for the sub-regions. These new capabilities include: pixel value histogramming, calculation of second-order statistics of skewness and kurtosis, one-dimensional autocorrelation length, and calculation of a scene clutter metric[6] for an image or image sub-region.

### 5.3.2 Scene Metrics

A Pascal program developed by Waterways Experiment Station WES, "SCENEMEZ" and a customized version titled "KRCMEZ", was applied to selected Standard Scenes imagery. This software was designed to calculate first and second order statistics for texture sub-regions of digitized imagery. Details of this software and its application to the Standard Scenes data are given in Appendix D.

A follow-up question from WES indicated that variance measures recorded for the Standard Scene imagery by the SCENEMEZ software seemed unusually high. Subsequently, output files of SCENEMEZ created at KRC were double-checked by comparing them both with the actual pixel values in the texture sub-regions, and also with statistics generated by KRC in-house (OS7) software. The results suggest that the version of SCENEMEZ tested by KRC is introducing default pixel values that cause variance-based calculations to be artificially high.

KRC's in-house software, OS7, was used to calculate descriptive statistics for a subset of the Standard Scenes database, the 24-hour sequence of thermal imagery for Standard Scene VI under late fall/early winter conditions. Figures on the following pages show results from OS7 computations that may be compared with those produced by SCENEMEZ. Table 5.3 lists statistical values for the image foreground of dried grasses, and Figures 5.45 through 5.48 graphically depict selected measures. Table 5.4 lists statistical values for the image treeline of bare, deciduous trees and brush, and Figures 5.49 through 5.52 graphically depict selected measures.

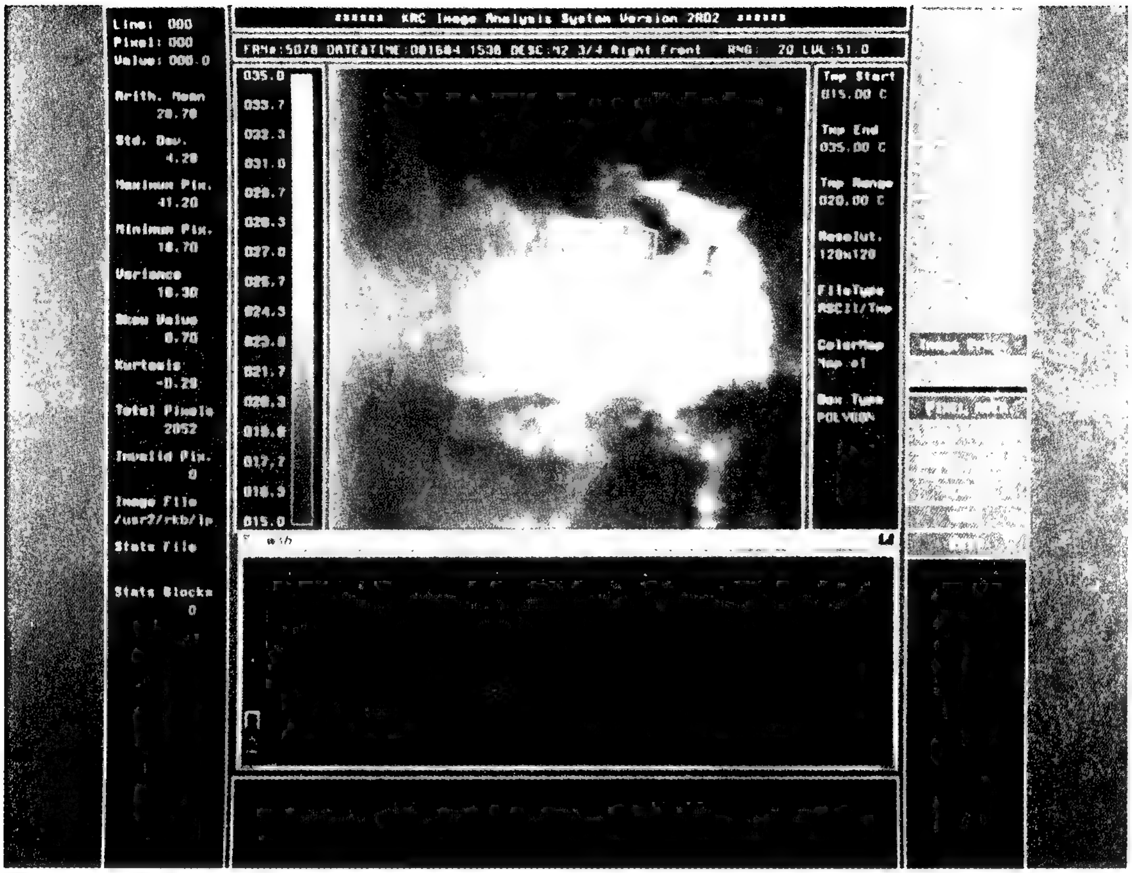



Figure 5.44: OS7 Menu Display with Image Processing Option Opened.

**Table 5.3: Temperature Statistics for Standard Scene VI Foreground of Dried Grasses.**

Values for 24-hour period during November, 1986. Calculated from long-wave infrared imagery using OS7 Software.

| date | time | mean | std | min | max | vari | skew | kurt |
|---|---|---|---|---|---|---|---|---|
| 110486 | 0600 | -5.357 | 0.130 | -5.000 | -5.700 | 0.017 | 0.395 | -0.141 |
| 110486 | 0700 | -6.134 | 0.110 | -5.700 | -6.300 | 0.012 | 1.180 | 1.223 |
| 110486 | 0800 | -7.350 | 0.096 | -7.000 | -7.500 | 0.009 | 0.567 | 0.161 |
| 110486 | 0900 | -5.986 | 0.120 | -5.600 | -6.200 | 0.014 | 0.564 | 0.348 |
| 110486 | 1000 | -4.019 | 0.187 | -3.500 | -4.400 | 0.035 | 0.018 | -0.596 |
| 110486 | 1100 | -2.630 | 0.244 | -2.000 | -3.200 | 0.060 | 0.113 | -0.547 |
| 110486 | 1200 | -1.678 | 0.663 | -0.200 | -3.100 | 0.439 | -0.286 | -0.738 |
| 110486 | 1300 | -0.664 | 0.714 | 1.300 | -2.400 | 0.510 | -0.225 | -0.378 |
| 110486 | 1400 | 2.277 | 0.603 | 3.500 | 0.900 | 0.363 | 0.133 | -1.030 |
| 110486 | 1500 | 2.330 | 0.504 | 3.900 | 1.100 | 0.254 | 0.125 | 0.018 |
| 110486 | 1600 | -0.596 | 0.428 | 0.700 | -1.400 | 0.183 | 0.662 | 0.246 |
| 110486 | 1603 | -1.180 | 0.484 | 0.000 | -2.200 | 0.234 | 0.320 | -0.510 |
| 110486 | 1700 | -3.759 | 0.423 | -2.400 | -4.800 | 0.179 | 0.469 | -0.151 |
| 110486 | 1800 | -5.452 | 0.440 | -4.300 | -6.500 | 0.194 | 0.281 | -0.613 |
| 110486 | 1900 | -5.844 | 0.619 | -3.300 | -7.300 | 0.383 | 0.685 | 0.812 |
| 110486 | 2001 | -4.872 | 0.433 | -3.800 | -6.300 | 0.188 | -0.111 | 0.130 |
| 110486 | 2100 | -5.996 | 0.456 | -4.700 | -7.200 | 0.208 | 0.142 | 0.448 |
| 110486 | 2200 | -3.303 | 0.326 | -2.300 | -4.300 | 0.106 | 0.101 | 0.007 |
| 110486 | 2300 | -5.297 | 0.366 | -4.000 | -6.300 | 0.134 | 0.006 | 0.513 |
| 110486 | 2400 | -4.321 | 0.292 | -3.400 | -5.400 | 0.085 | -0.182 | 0.106 |
| 110586 | 2459 | -4.097 | 0.216 | -3.600 | -4.700 | 0.047 | -0.220 | -0.030 |
| 110586 | 2600 | -3.506 | 0.251 | -3.000 | -4.300 | 0.063 | -0.410 | -0.182 |
| 110586 | 2700 | -4.383 | 0.328 | -3.200 | -5.100 | 0.108 | 0.262 | -0.159 |
| 110586 | 2759 | -2.763 | 0.195 | -2.300 | -3.200 | 0.038 | 0.048 | -0.723 |
| 110586 | 2900 | -3.553 | 0.139 | -3.000 | -3.800 | 0.019 | 0.626 | 0.351 |
| 110586 | 3000 | -1.334 | 0.157 | -0.700 | -1.700 | 0.025 | 0.755 | 1.061 |

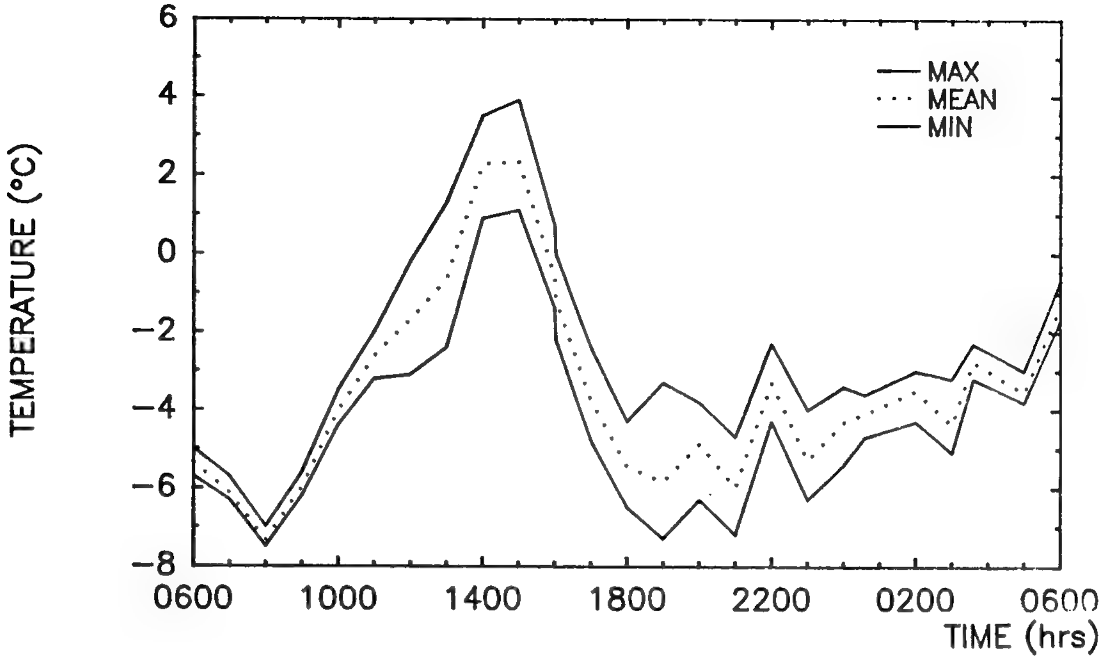



**Figure 5.45: Average and Range, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.**

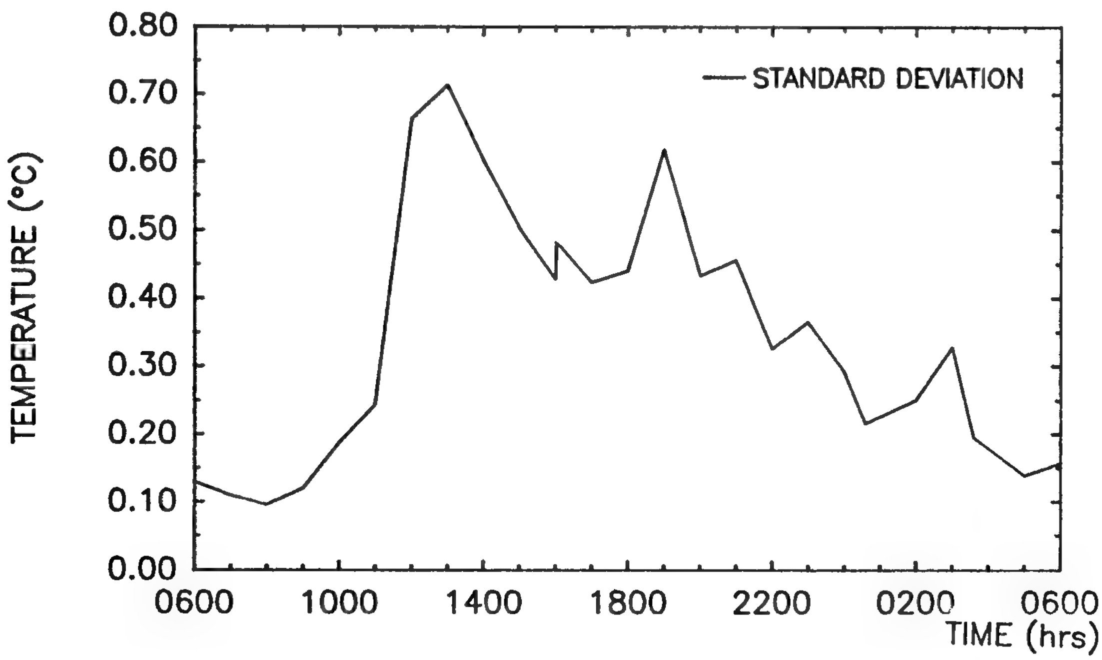



**Figure 5.46: Standard Deviation, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.**

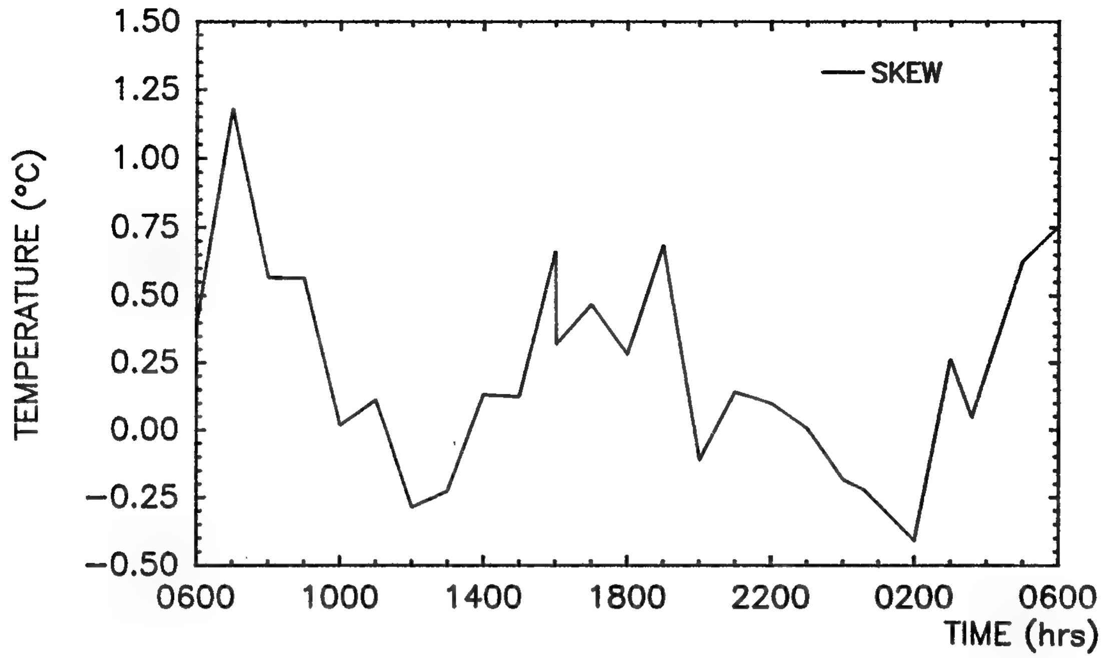



**Figure 5.47: Skewness, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.**

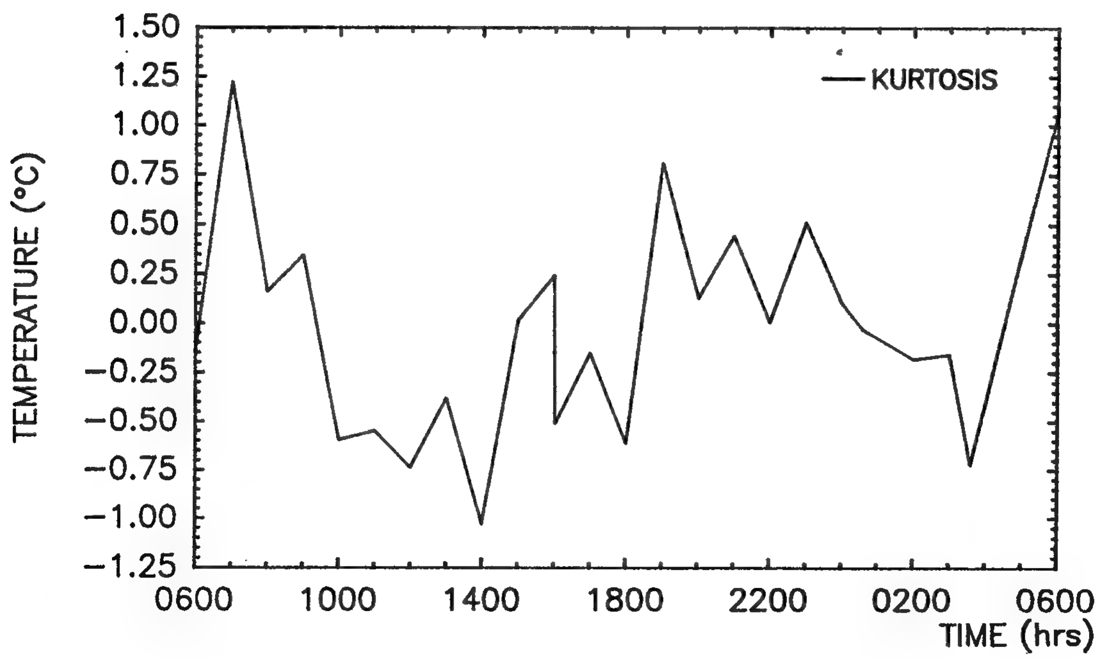



**Figure 5.48: Kurtosis, Apparent Temperature Distribution for Standard Scene VI Foreground, across 24-Hour Period, November, 1986.**

**Table 5.4: Temperature Statistics for Standard Scene VI Treeline of Deciduous Trees.**

For 24-hour period during November, 1986. Calculated from long-wave infrared imagery using OS7 Software.

| date | time | mean | stdev | min | max | vari | skew | kurt |
|---|---|---|---|---|---|---|---|---|
| 110486 | 0600 | -4.846 | 0.221 | -4.300 | -5.500 | 0.049 | 0.032 | -0.252 |
| 110486 | 0800 | -7.112 | 0.146 | -6.700 | -7.400 | 0.021 | 0.492 | -0.293 |
| 110486 | 0900 | -5.996 | 0.125 | -5.500 | -6.200 | 0.016 | 0.719 | 0.500 |
| 110486 | 1000 | -4.187 | 0.168 | -3.500 | -4.500 | 0.028 | 0.824 | 0.708 |
| 110486 | 1100 | -3.055 | 0.158 | -2.400 | -3.400 | 0.025 | 0.917 | 1.410 |
| 110486 | 1200 | -2.381 | 0.392 | -0.100 | -3.200 | 0.154 | 1.837 | 5.476 |
| 110486 | 1300 | -1.565 | 0.388 | 0.300 | -2.300 | 0.151 | 0.768 | 1.004 |
| 110486 | 1400 | 2.391 | 0.446 | 4.300 | 1.100 | 0.199 | 0.470 | 1.055 |
| 110486 | 1500 | 2.203 | 0.280 | 3.700 | 1.600 | 0.078 | 0.442 | 0.682 |
| 110486 | 1600 | 0.467 | 0.291 | 1.500 | -0.200 | 0.085 | 0.311 | 0.089 |
| 110486 | 1603 | 0.090 | 0.326 | 0.900 | -0.700 | 0.106 | 0.086 | -0.738 |
| 110486 | 1700 | -2.113 | 0.371 | -1.000 | -3.100 | 0.138 | 0.112 | 0.065 |
| 110486 | 1800 | -3.702 | 0.502 | -2.700 | -5.200 | 0.252 | -0.313 | -0.396 |
| 110486 | 1900 | -4.268 | 0.540 | -3.000 | -5.800 | 0.291 | -0.003 | -0.433 |
| 110486 | 2001 | -3.615 | 0.375 | -2.700 | -4.800 | 0.140 | -0.151 | 0.102 |
| 110486 | 2100 | -4.385 | 0.442 | -3.400 | -5.700 | 0.196 | -0.116 | -0.175 |
| 110486 | 2200 | -2.311 | 0.238 | -1.600 | -3.000 | 0.057 | 0.442 | 0.419 |
| 110486 | 2300 | -4.260 | 0.296 | -3.500 | -5.100 | 0.087 | 0.406 | -0.158 |
| 110486 | 0000 | -3.467 | 0.258 | -2.700 | -4.300 | 0.066 | 0.147 | 0.136 |
| 110586 | 0059 | -3.336 | 0.228 | -2.700 | -3.900 | 0.052 | 0.203 | -0.136 |
| 110586 | 0200 | -2.808 | 0.258 | -2.200 | -3.600 | 0.066 | 0.079 | 0.046 |
| 110586 | 0300 | -3.584 | 0.285 | -2.800 | -4.400 | 0.081 | 0.318 | 0.233 |
| 110586 | 0359 | -2.123 | 0.224 | -1.500 | -2.700 | 0.050 | 0.120 | -0.406 |
| 110586 | 0500 | -3.315 | 0.168 | -2.800 | -3.800 | 0.028 | 0.311 | 0.035 |
| 110586 | 0600 | -1.221 | 0.170 | -0.600 | -1.600 | 0.029 | 0.620 | 0.413 |

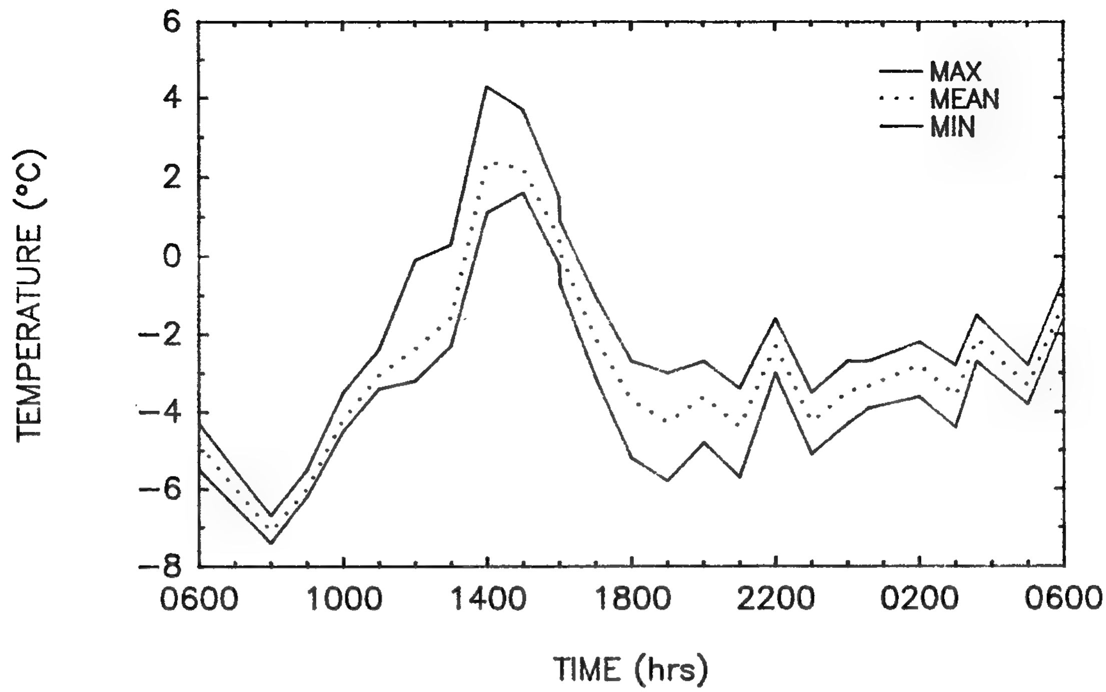



**Figure 5.49: Average and Range, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.**

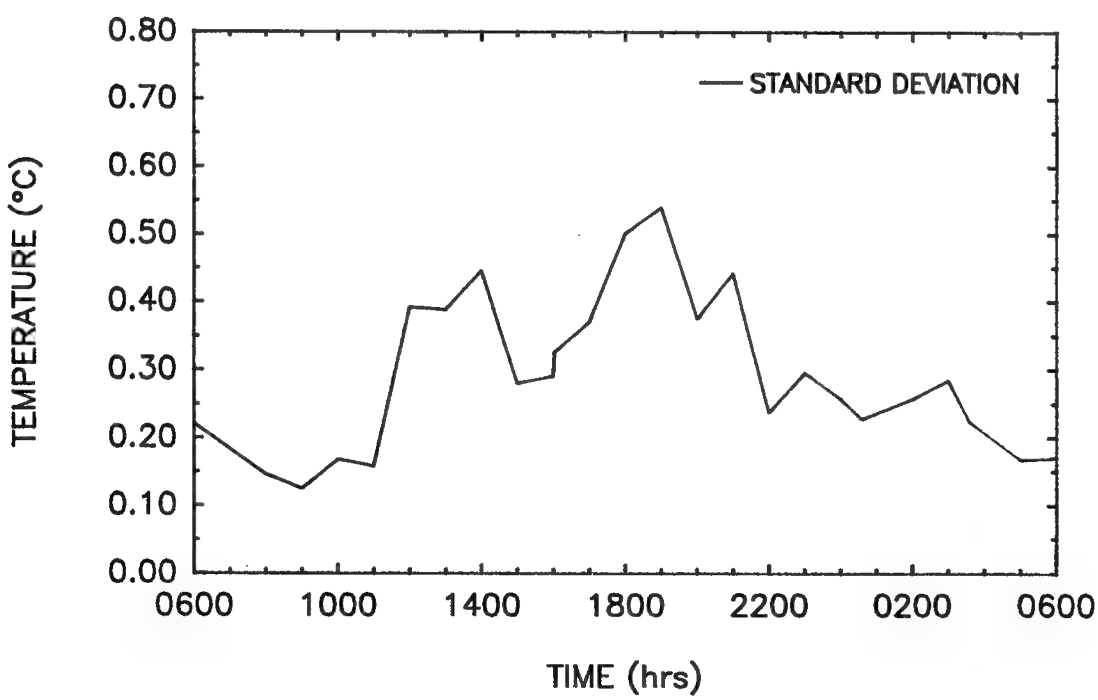



**Figure 5.50: Standard Deviation, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.**

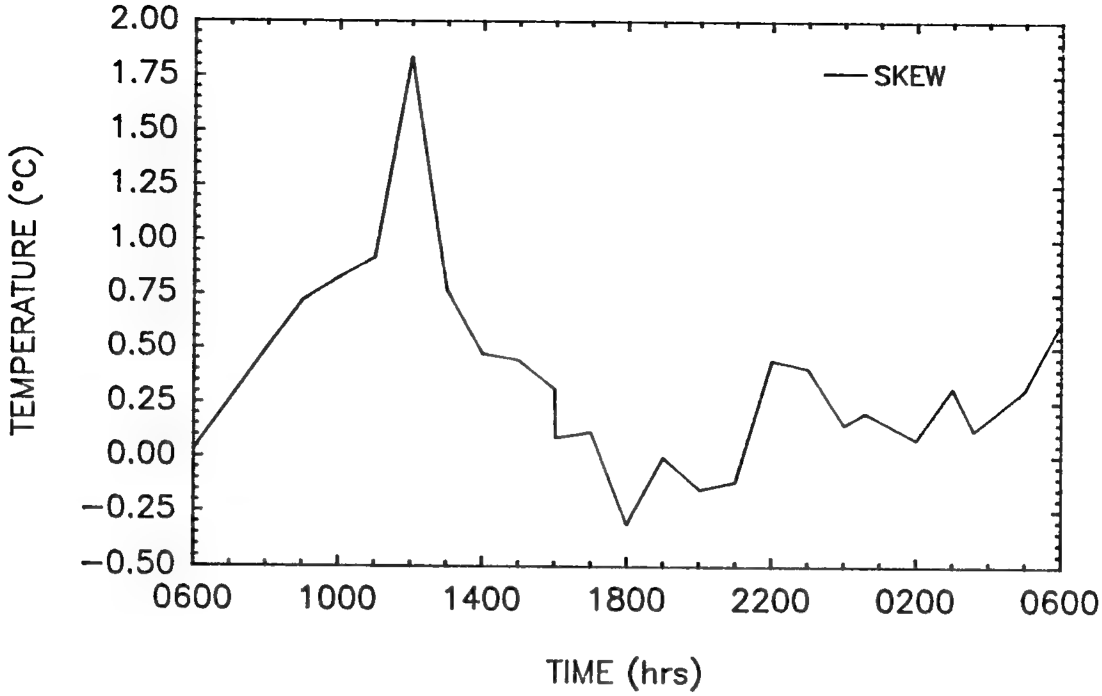



**Figure 5.51: Skewness, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.**

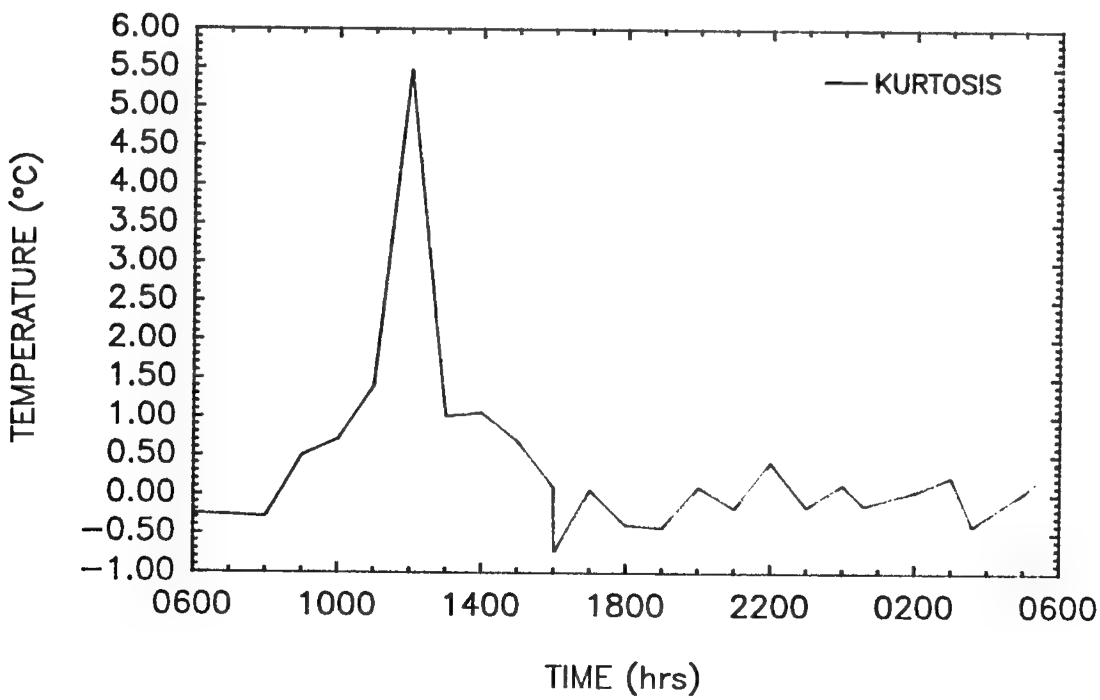



**Figure 5.52: Kurtosis, Apparent Temperature Distribution for Standard Scene VI Treeline, across 24-Hour Period, November, 1986.**

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## A.1 Meteorological Data

Meteorological conditions during the FED MAC experiment were monitored at the KRC Primary site by means of a portable weather station comprised of an instrumentation tower, data acquisition loggers and pc-based automated data recording system operating on field power. Fifty-one channels of input data were recorded as part of this test; the data acquisition loggers are capable of monitoring up to 500 total analog and thermocouple inputs. Data on meteorological parameters particularly relevant to study of thermal infrared signatures were extracted and organized into computer files as described below.

### A.1.1 Description of Data, Files and File Format

Each KRC meteorological data file includes observations for one test day. Files may be organized according to actual time of day (military clock), or by elapsed time, as shown in the file excerpts in Tables A.1 and A.2. Each file has a two-line header that identifies the date, start time, and test site at which the data was collected.

Files organized by time of day include "W090990.DAT" which contains observations beginning at 0805 hours on 09/09/90, and "W091090.DAT" which has data beginning at 0720 hours on 09/10/90 (and continuing to the end of the test on 09/11/90). The format of these files is:

TIME, AIRT(EDGE), AIRT(OPN), SOLAR, WINDSPD, HUMID, LWIR, WINDIR

FORMAT(I4,7F9.3)

where:

| | |
|---|---|
| TIME | Time of day (0000 to 2400 hours) |
| AIRT(EDGE) | Air Temperature (°C) at edge of forest |
| AIRT(OPN) | Air Temperature (°C) in open field |
| SOLAR | Solar Irradiance ($W/M^2$) |
| WINDSPD | Wind Speed (M/sec) |
| HUMID | Relative Humidity (%) |
| LWIR | Longwave Infrared Radiation |
| WINDIR | Wind Direction (0 - 360%) |

Files organized by elapsed time include "ELPT0909.DAT" which contains observations beginning at 0805 hours on 09/09/90, and "ELPT0910.DAT" which has data beginning at 0720 hours on 09/10/90 (and continuing to the end of the test on 09/11/90). The format of these files is:

TIMELAPSE, AIRT(EDGE), AIRT(OPN), SOLAR, WINDSPD, HUMID, LWIR, WINDIR

FORMAT(F8.3,1X,7F9.3)

where all variables are the same as listed above, with the exception of TIMELAPSE, which is elapsed time in hours.

### A.1.2 Data Plots

Figures on the following pages graphically depict the data for six significant meteorological parameters recorded at the KRC primary site during the FED MAC 1990 experiment. These are environmental variables that either have a direct influence on the thermal signature of exposed surfaces, or affect heat transfer processes on those surfaces. Ambient air Temperature ($^oC$) at edge of forest and in the open field are shown in Figure A.1. Solar irradiance ($W/M^2$) is shown in Figure A.2, and longwave infrared radiation in A.3 Figure A.4 depicts relative humidity (%). Figures A.5 and A.6 show wind speed (M/sec) and wind direction ($0 - 360^o$ clockwise from north), respectively.

## A.2 Soil Temperature Profile from Meteorological Station Data

### A.2.1 Description of Data, Files and File Format

Information on soil temperature was collected from the large probe set next to the weather tower. Readings were automatically recorded at five minute intervals by the meteorological station computer. As shown in the file excerpt in Table A.3, the file has a two-line header that identifies the file type, date, and test site at which the data was collected.

Files "ST090990.ME" and "ST091090.ME" contain data from the main weather tower soil probe, for 09 September, and 10-11 September, respectively. The format of these files is:

TIME, T00CM, T01CM, T05CM, T10CM, T20CM, T50CM

FORMAT(I4,6F9.3)

where:

| | |
|---|---|
| TIME | Time of day (0000 to 2400 hours) |
| T00CM | Soil Temperature ($^oC$) at the surface (0 cm. depth) |
| T01CM | Soil Temperature ($^oC$) at 1 cm. depth |
| T05CM | Soil Temperature ($^oC$) at 5 cm. depth |
| T10CM | Soil Temperature ($^oC$) at 10 cm. depth |
| T20CM | Soil Temperature ($^oC$) at 20 cm. depth |
| T50CM | Soil Temperature ($^oC$) at 50 cm. depth |

**Table A.1: Meteorological data file organized by time**
Excerpt of file "08050909.DAT" showing 2-line header and data.

```
KRC Met Data: 09/09/90.  Start time: 0805.  Site: FED MAC.  Howland, ME.
TIME AIRT(EDGE) AIRT(OPN) SOLAR  WINDSPD   HUMID    LWIR    WINDDIR
0805      6.100     5.800 258.376   0.235  98.941  323.044  231.894
0810      6.500     6.400 266.691   1.888  98.735  323.044  201.276
0815      7.200     7.100 274.882   1.382  98.571  324.186  204.174
0820      7.600     7.500 290.642   1.213  98.988  322.588  185.922
0825      7.700     7.700 309.754   1.368  98.694  320.990  185.922
0830      8.100     8.100 322.412   1.223  98.229  320.077  192.618
0835   -999.000     8.700 336.807   1.193  98.024  318.022  177.012
0840      9.700     8.900 351.451   1.734  95.884  317.109  170.586
0845     10.300     9.700 356.043   0.942  94.694  318.478  169.524
0850     10.900    10.200 358.525   1.068  91.562  314.826  207.180
0855     11.700    10.800 374.286   1.247  89.661  312.771  193.320
0900     12.600    11.300 386.075   0.563  85.976  310.716  176.400
0905     12.900    11.800 417.472   1.045  83.910  310.945  198.936
```

**Table A.2: Meteorological data file organized by elapsed time**
Excerpt of file "0909ELPT.DAT" showing 2-line header and data.

```
 KRC Met Data: 09/09/90.  Elapsed time start: 0805.  Site: FED MAC.  ME
TIMELAPSE AIRT(EDGE) AIRT(OPN) SLOAR  WINDSPD   HUMID    LWIR    WINDDIR
   0.000       6.100     5.800 258.376   0.235  98.941  323.044  231.894
   0.083       6.500     6.400 266.691   1.888  98.735  323.044  201.276
   0.167       7.200     7.100 274.882   1.382  98.571  324.186  204.174
   0.250       7.600     7.500 290.642   1.213  98.988  322.588  185.922
   0.333       7.700     7.700 309.754   1.368  98.694  320.990  185.922
   0.417       8.100     8.100 322.412   1.223  98.229  320.077  192.618
   0.500       -----     8.700 336.807   1.193  98.024  318.022  177.012
   0.583       9.700     8.900 351.451   1.734  95.884  317.109  170.586
   0.667      10.300     9.700 356.043   0.942  94.694  318.478  169.524
   0.750      10.900    10.200 358.525   1.068  91.562  314.826  207.180
   0.833      11.700    10.800 374.286   1.247  89.661  312.771  193.320
   0.917      12.600    11.300 386.075   0.563  85.976  310.716  176.400
   1.000      12.900    11.800 417.472   1.045  83.910  310.945  198.936
```

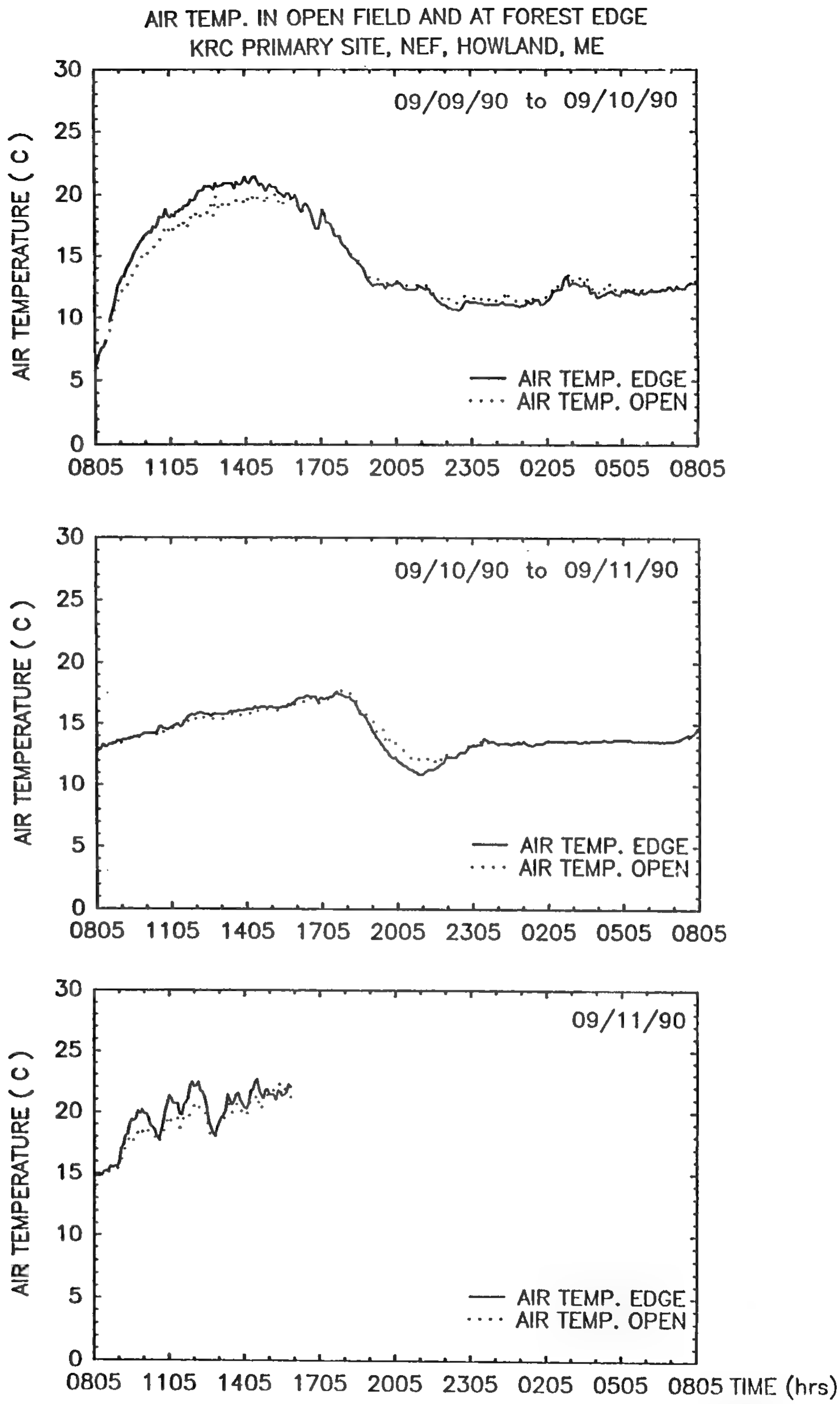


**Figure A.1: Air Temperatures (°C) in Open Field and at Forest Edge**
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

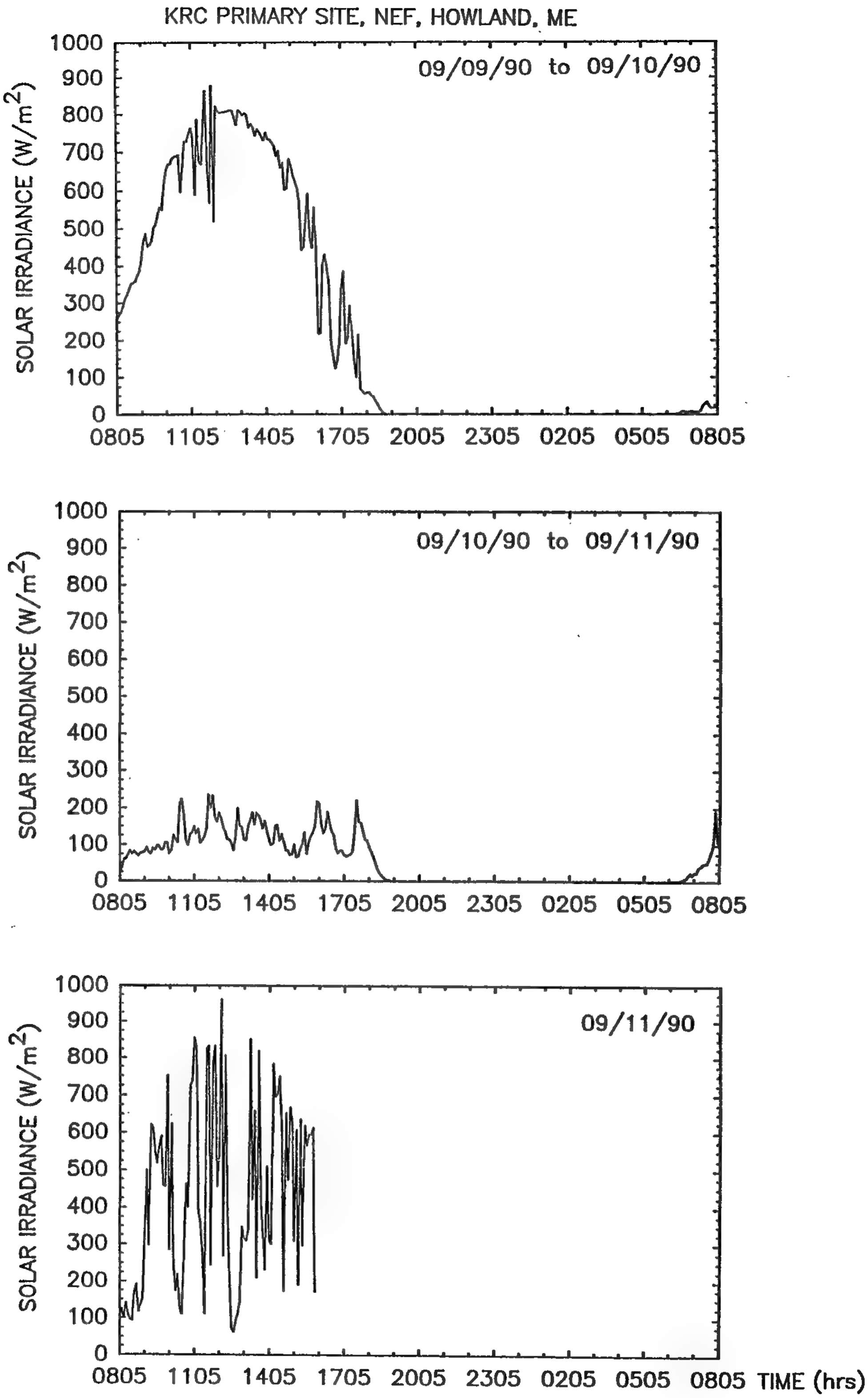


**Figure A.2: Solar Irradiance** ($W/m^2$)
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

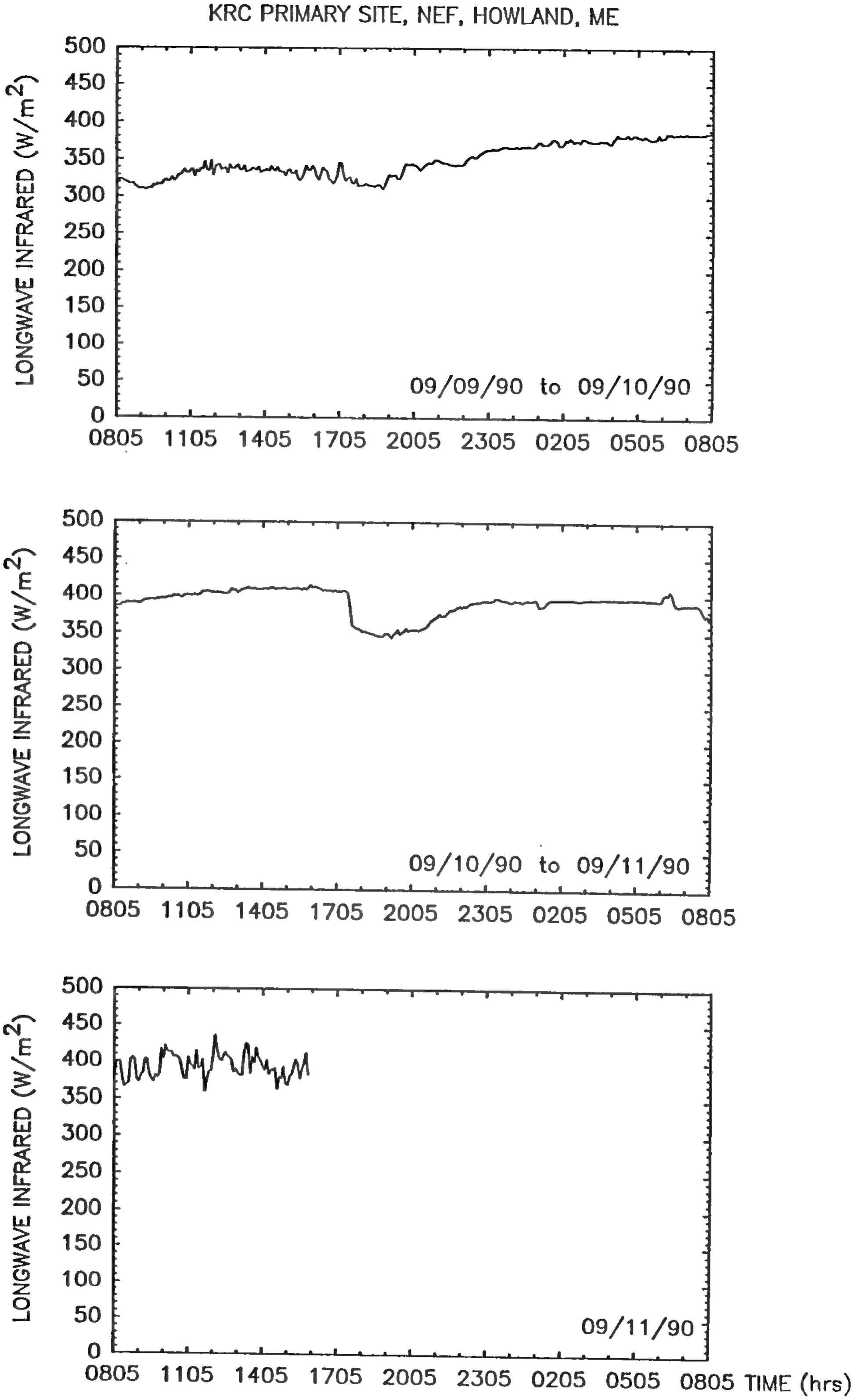


**Figure A.3: Longwave Infrared ($W/m^2$)**
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

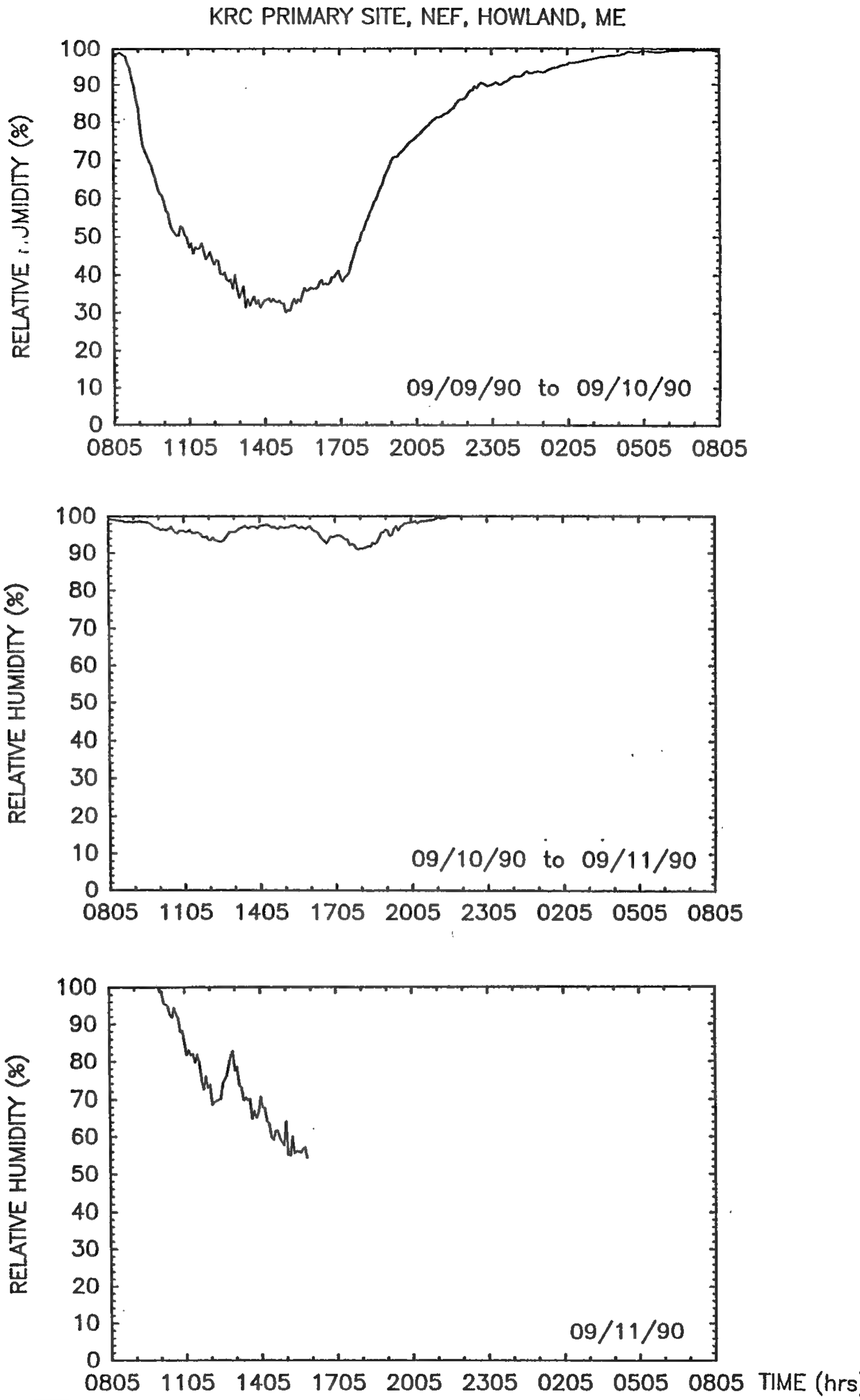


**Figure A.4: Relative Humidity (%)**
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

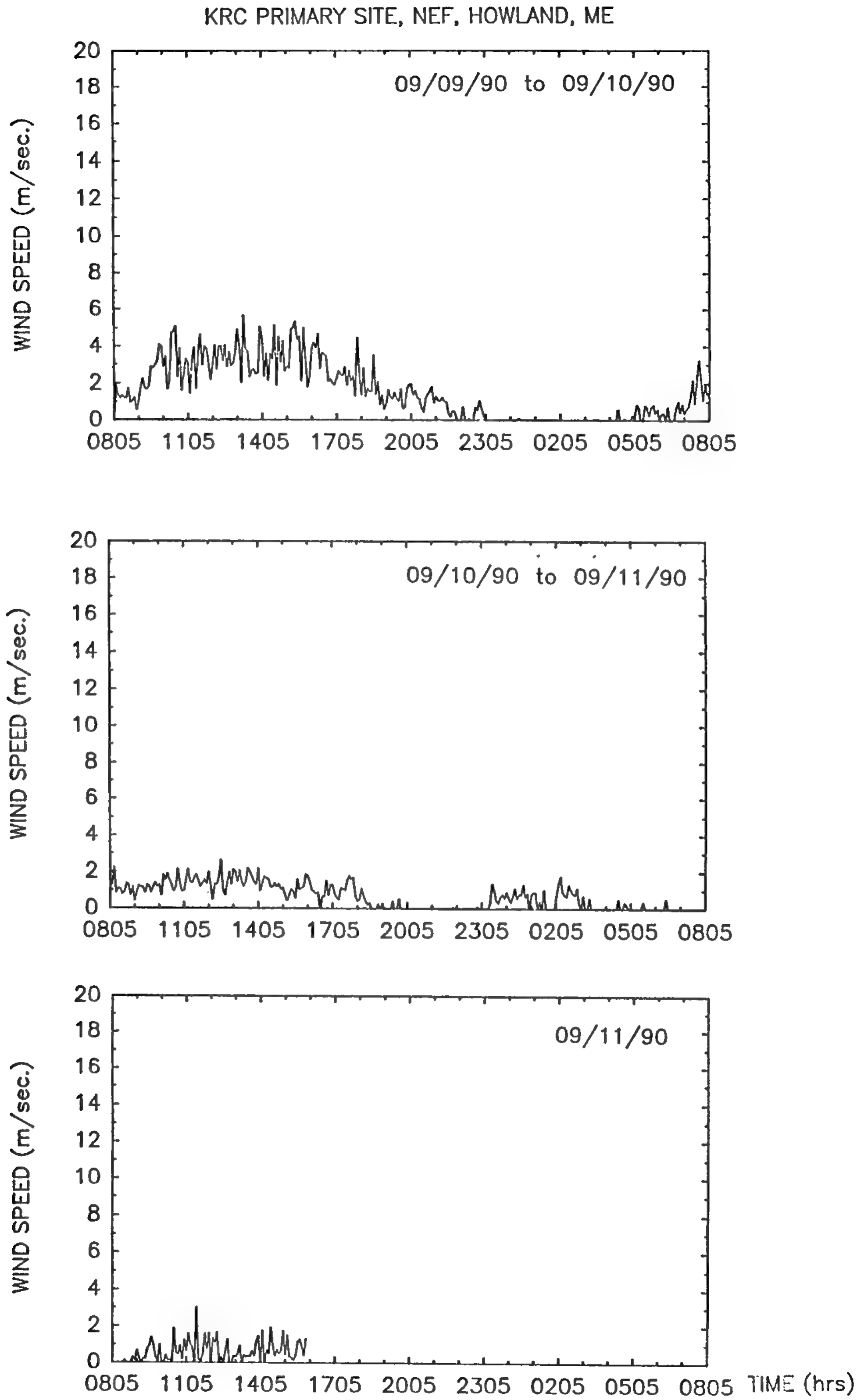


**Figure A.5: Wind Speed (m/sec)**
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

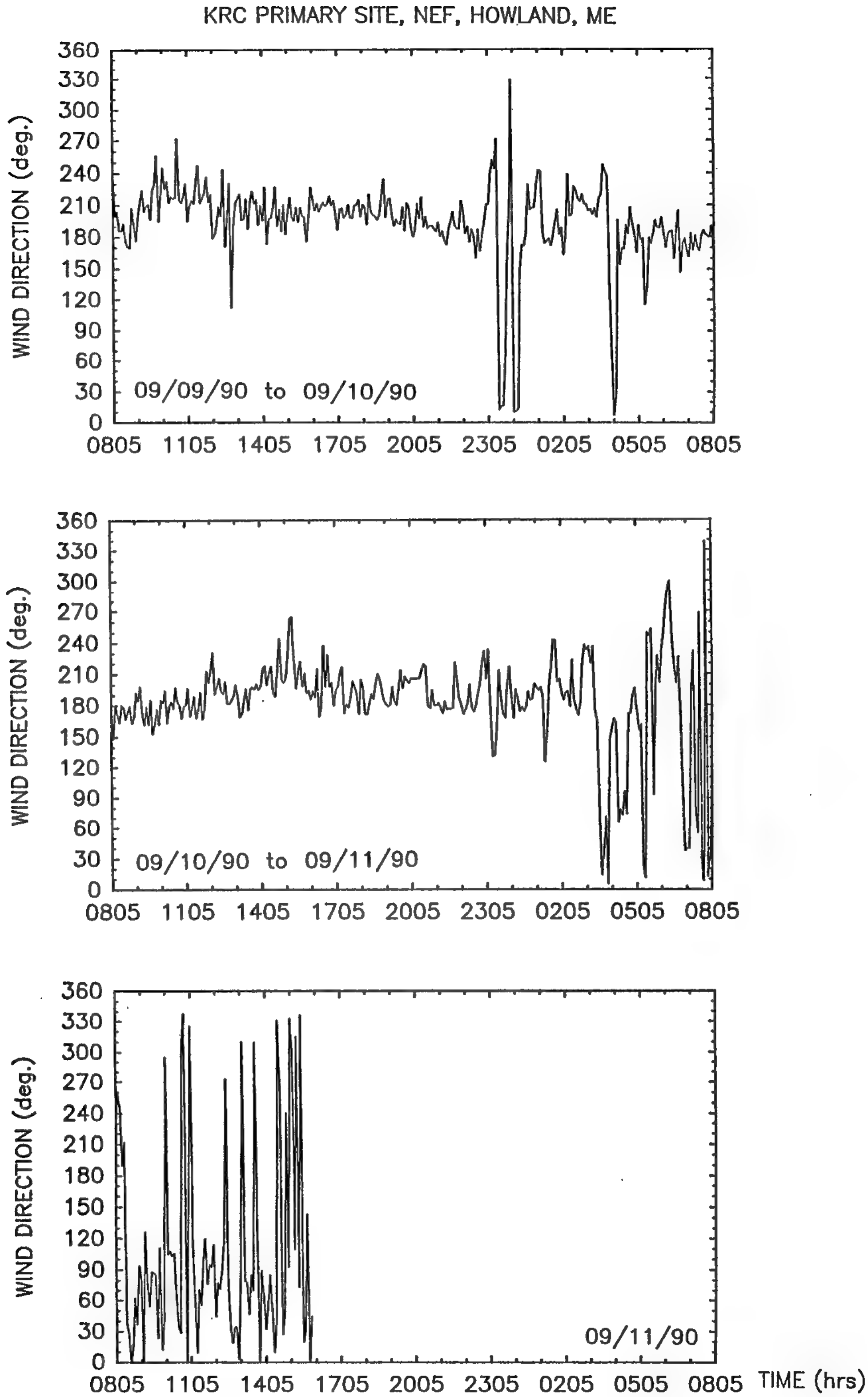


**Figure A.6: Wind Direction (Degrees)**
Recorded at KRC Primary Site, NEF, Howland, Maine for dates shown.

### A.2.2 Data Plots

Figures on the following pages graphically depict the soil temperature data recorded at various depths, at KRC primary site during the FED MAC 1990 experiment. Data from soil temperatures are depicted in terms of comparing readings from the thermocouples at the meteorological station, set at specific depths, across time. (A schematic of the location of the meteorological station was given in Section 5.1. in the main text of this report.) Figures A.7 and A.8 compare soil temperature readings across time at 0, 1, and 5 cm, and at 10, 20, and 50 cm, respectively.

## A.3 Forest Edge Soil Temperature Transect Data

### A.3.1 Description of Data, Files and File Format

Information on soil temperatures was collected from the probes set for the soil temperature transect into the forest edge. All readings were automatically recorded at five minute intevals by the meteorological computer. These files contain a two-line header that identifies the file type, date, and test site at which the data was collected. An excerpt of a soil temperature transect data file is shown in Table A.4.

Files "ST090990.TRA" and "ST091090.TRA" contain data from the probes set for the soil transect into the forest edge, for 09 September, and 10-11 September, respectively. Their format is:

TIME, CH41, CH42, CH43, CH44, CH45, CH46, CH47, CH48, CH49, CH50, CH51, CH52

FORMAT(I4,12F9.3)

where:

| | |
|---|---|
| TIME | Time of day (0000 to 2400 hours) |
| CH41 | Soil Temperature (°C), Location A, 5 cm. depth |
| CH42 | Soil Temperature (°C), Location A, 0 cm. depth |
| CH43 | Soil Temperature (°C), Location B, 5 cm. depth |
| CH44 | Soil Temperature (°C), Location B, 0 cm. depth |
| CH45 | Soil Temperature (°C), Location C, 5 cm. depth |
| CH46 | Soil Temperature (°C), Location C, 0 cm. depth |
| CH47 | Soil Temperature (°C), Location D, 5 cm. depth |
| CH48 | Soil Temperature (°C), Location D, 0 cm. depth |
| CH49 | Soil Temperature (°C), Location A, 15 cm. depth |
| CH50 | Soil Temperature (°C), Location B, 15 cm. depth |
| CH51 | Soil Temperature (°C), Location C, 15 cm. depth |
| CH52 | Soil Temperature (°C), Location D, 15 cm. depth |

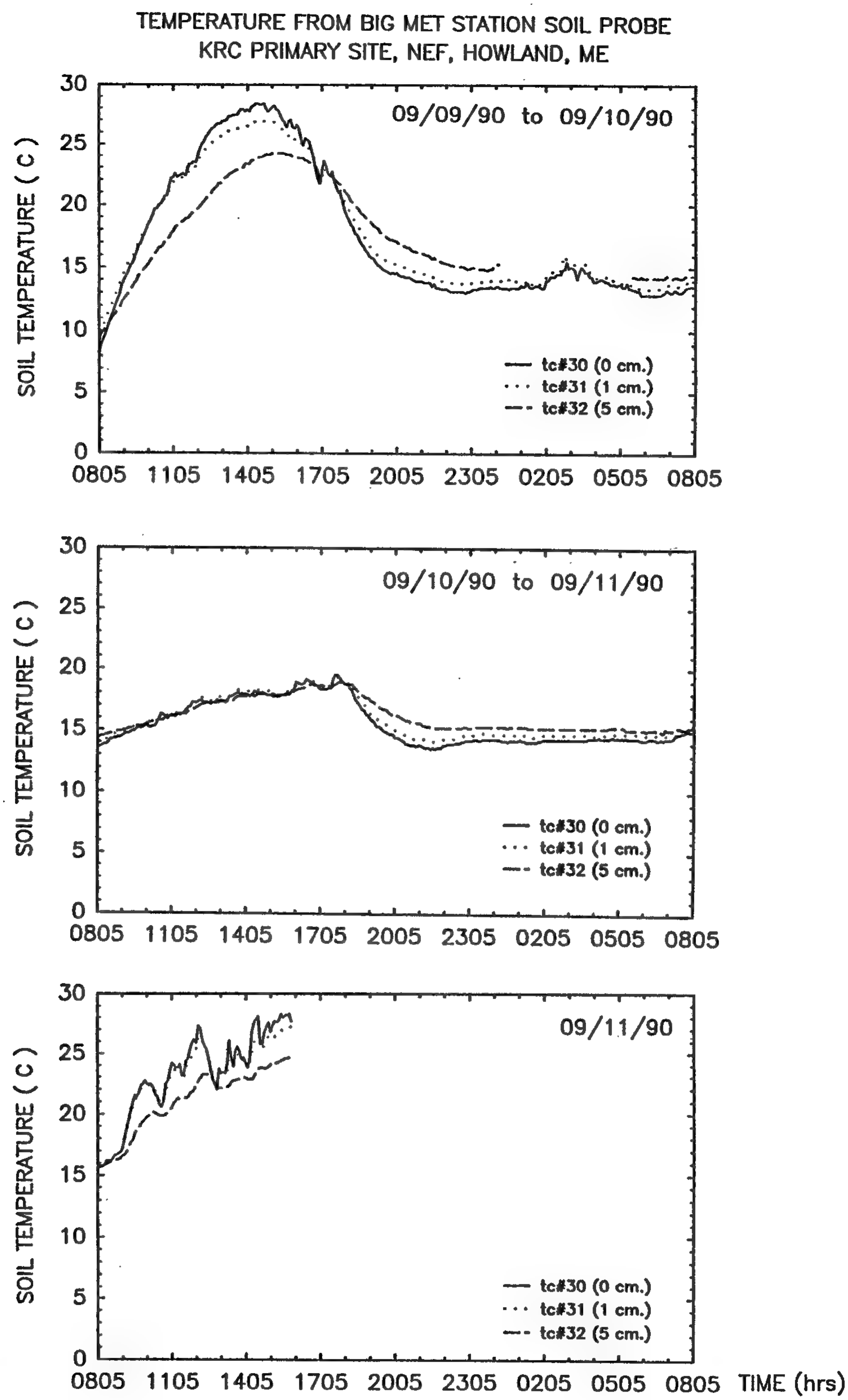


**Figure A.7: Soil Temperatures (°C) at 0, 1, and 5 cm Depths, Main Soil Probe** Recorded at KRC Primary Site meteorological tower soil probe in open field, NEF, Howland, Maine for dates shown.

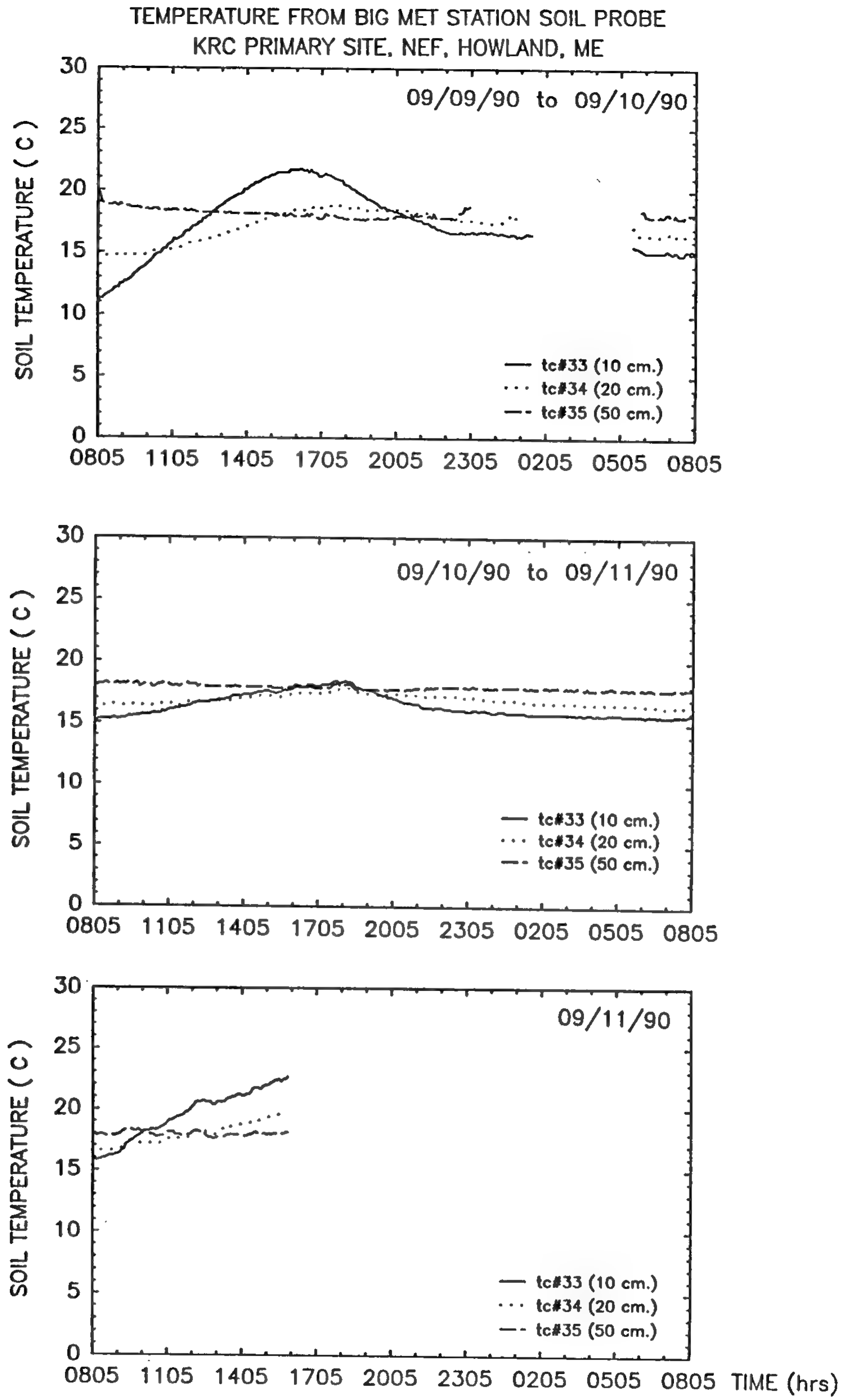


**Figure A.8: Soil Temperatures (°C) at 10, 20, and 50 cm Depths, Main Soil Probe**
Recorded at KRC Primary Site meteorological tower soil probe in open field, NEF, Howland, Maine for dates shown.

Graphic presentations of soil transect data are included in the discussion section in the main body of this report.

## A.4 Leaf Area Index of Treeline Gap

Leaf density or Leaf Area Index (LAI) is measured to help model thermal process essential to plant growth. These process, which are all dependent on the density and orientation of the canopy foliage, include: radiative transfer, conduction, transpiration, evaporation, and gaseous exchange into and out of the canopy. LAI, the total area of vegetative material in a prescribed layer of plant canopy per unit ground area, is used to define the solar shielding factor $\sigma_f$. The value of the solar shielding factor ranges from 0, signifying no foliage, to 1, signifying complete radiative blocking.

### A.4.1 Testing Procedure

The LICOR LAI-2000 used to measure LAI has an optical sensor that consists of a group of five ring-shaped radiation detectors arranged concentrically. The LAI-2000 computes a gap fraction, which is the ratio of light transmitted through the canopy to light that is incident on the canopy, for each sensor view ring.

Measurements were performed with two identical LAI-2000 units, designated as ABOVE ("A") and BELOW ("B") units, respectively. Unit A was placed 10 meters east of the KRC meteorological tower so as to obtain an unrestricted field of view of the clear sky, and logged the above canopy readings automatically every 15 seconds. Unit B was manually controlled to record the below canopy values. The logging units were later connected to combine data files, and a canopy LAI computed.

**Table A.3: Ground Probe Soil Temperature Data**
Excerpt of file "09TC3035" showing 2-line header and data.

KRC Ground Probe Temperature Data: 09/09/90. Howland, ME.

| TIME | T00CM | T01CM | T05CM | T10CM | T20CM | T50CM |
|---|---|---|---|---|---|---|
| 0805 | 8.200 | 8.900 | 9.100 | 10.900 | 14.400 | 19.600 |
| 0810 | 8.800 | 9.600 | 9.800 | 11.400 | 14.600 | 19.800 |
| 0815 | 9.300 | 10.300 | 9.900 | 11.300 | 14.700 | 19.100 |
| 0820 | 9.700 | 10.800 | 10.200 | 11.500 | 14.700 | 18.900 |
| 0825 | 10.200 | 11.300 | 10.400 | 11.600 | 14.700 | 18.800 |
| 0830 | 10.700 | 11.600 | 10.700 | 11.700 | 14.700 | 18.800 |
| 0835 | 11.200 | 12.000 | 11.000 | 11.800 | 14.700 | 18.800 |
| 0840 | 11.600 | 12.300 | 11.200 | 11.900 | 14.700 | 18.800 |
| 0845 | 12.100 | 12.800 | 11.400 | 12.100 | 14.700 | 18.900 |
| 0850 | 12.500 | 13.300 | 11.700 | 12.200 | 14.800 | 18.800 |
| 0855 | 12.900 | 13.700 | 11.800 | 12.200 | 14.600 | 18.700 |
| 0900 | 13.600 | 14.300 | 12.300 | 12.500 | 14.800 | 18.900 |

**Table A.4: Soil Temperature Transect Data (Wrapped file)**
Excerpt of file "090990" showing 2-line header and data (wrapped).

```
KRC Soil Temperatures Transect Data: 09/09/90.  Site Fed Mac test, Howland, ME.
TIME      CH41      CH42      CH43      CH44      CH45      CH46      CH47      CH48
 CH49      CH50      CH51      CH52
0805      9.200     8.700     10.300    6.800     10.400    6.700     8.800     4.900
 14.900    13.800    13.300    12.100
0810      9.400     8.900     10.300    6.900     10.500    6.800     8.800     5.100
 14.900    13.800    13.300    12.100
0815      9.600     9.200     10.300    7.100     10.600    7.000     8.800     5.300
 15.000    13.800    13.300    12.100
0820      9.700     9.800     10.400    7.300     10.600    7.300     8.900     5.600
 15.000    13.800    13.300    12.200
```

Initial measurements were made according to the location of the sites A, B, C, and D described for the soil temperature transect, in the forest gap (see Figure 5.5 in the main body of the report for a schematic of the soil temperature transect). The data sets listed below show the LAIs at, to the left, and to the right of each thermocouple site. With these and other readings taken deeper in the gap, an average of 40 readings were obtained around the entire gap.

### A.4.2 Description of Data, Files and File Format

File "MAINE.LAI" contains LAI and related data. Table A.5 contains an excerpt from this file showing one complete set of measurements. Each set of measurements consists of a one-line header, followed by a set of five parameters - each of which is computed for each of the five view rings - and finally by an ordered sequence of input data values from the A and B units.

The header contains the following information:

FILE, DATE, TIME, HEIGHT, POSITION, LAI, SEL, DIFN, MTA, SEM, SMP

where:

| | |
|---|---|
| FILE | index number of the set of observations |
| DATE | date (day and month) on which observations made |
| TIME | time of day (HR:MIN:SEC, 24-hour clock) observations initiated |
| HEIGHT | label describing height of instrument |
| POSITN | label describing location of instrument |
| LAI | leaf area index computed from the set of observations in the file |
| SEL | standard error of the LAI determination |
| DIFN | diffuse non-interceptance, the fraction of sky visible beneath the canopy |
| MTA | mean tip angle computed from the set of observations in the file |
| SEM | standard error of the mean tip angle determination |
| SMP | number of samples |

The header is followed by a set of parameters. Five values, corresponding to the five view rings, are given for each parameter:

ANGLES,CNTCT,STDDEV,DISTS,GAPS

where:

| | |
|---|---|
| ANGLES | the view angle (degrees) of each ring |
| CNTCT | the average contact number for each ring; calculated as the natural logarithm of the gap fraction divided by the path length ($1/\cos\theta$) |

| | |
|---|---|
| STDDEV | standard error of the contact frequencies |
| DISTS | path length from the sensor to the edge of the canopy; typically, $1/cos\theta$ is used for the uniform canopy assumption |
| GAPS | average gap fraction, or transmission through the canopy, for each ring; calculated from sets of A (above canopy, or incident light) and B (beneath canopy, or transmitted light) readings |

Finally, input data in the format

UNIT,OBSNO,TIME,RING1,RING2,RING3,RING4,RING5

where:

| | |
|---|---|
| UNIT | identifier of LAI-2000 unit on which observations recorded:<br>A (above canopy, or incident light)<br>B (beneath canopy, or transmitted light) |
| OBSNO | observation number in sequence of 10 observations/file |
| TIME | time of day (HR:MIN:SEC, 24-hour clock) at which observations recorded |
| RING1 | amount of light measured by the $7^o$ ring |
| RING2 | amount of light measured by the $23^o$ ring |
| RING3 | amount of light measured by the $38^o$ ring |
| RING4 | amount of light measured by the $53^o$ ring |
| RING5 | amount of light measured by the $68^o$ ring |

The measure of the amount of light registered by RING1, etc is a calibrated, dimensionless reading. A blank line separates each set of measurements from the next set.

## A.5 Thermal Imagery and Spot Radiometric Data

### A.5.1 Description of Thermal Imagery and Data

Thermal imagery from the Maine field test is digitized for processing, using a PC-based Data Translation frame grabber. Each binary digit frame is supplemented by information from the corresponding frame of blackbody imagery, and converted into a calibrated temperature pixel frame. The temperature value assigned to a pixel is an apparent, or blackbody equivalent temperature, i.e., a blackbody at that temperature would emit the equivalent amount of radiation, in band, that was detected by the thermal imager.

### A.5.2 Thermal Imagery, Primary Site

**Description of Data, Files and File Format**

Thermal imagery for the primary site was collected using the commercially availiable IR imaging system, Inframetrics model 610. As shown in the file excerpt in Table A.6, each file has a one-line header that identifies the file type, date, and test site at which the data was collected. Variables in the header, and the format of the header are:

FRAMENO,DATE,TIME,DESCRIB,RANGE

FORMAT(5X,I5,11X,I6,1X,I4,6X,A20,5X,I4)

where:

| | |
|---|---|
| FRAMENO | Frame number assigned to image |
| DATE | Month, Day, and Year (MMDDYY) of test |
| TIME | Time of day (24-hour clock) |
| DESCRIB | Brief description of image contents |
| RANGE | Temperature range ($^oC.$). Common values are $2^o, 5^o, 10^o, 20^o, 50^o, 100^o, 200^o$. |

The following records give line-by-line data on pixel temperatures, in a format that depends on sensor capabilities and resolution of the image data. Typical image sizes are 128x128 pixels, 256x256 pixels, or 512x512 pixels. The format of the pixel temperature data is:

PTEMP(I,J)

FORMAT(M(S(16I5,/)))

where:

I = 1,2,...,R where R = total number of Rows in image (128, 256, or 512)
J = 1,2,...,C where C = total number of Columns in image (128, 256, or 512)
S = R/16

and

| | |
|---|---|
| PTEMP(I,J) | Temperature of the pixel in row I, column J stated as **degrees Kelvin times 10**. |

Pixel values are thus read from the upper left-hand corner of the image, row by row, ending with the pixel in the lower right-hand corner of the image. Note that pixel temperatures are stated as degrees Kelvin times 10 and thus will appear as rather large values in the data file. **Pixel values of PTEMP(I,J)=0 indicate border pixels, and are not elements of the image.** All image data files must therefore be manipulated to convert temperature

**Table A.5: Leaf Area Index Data**
Excerpt of file "MAINE.LAI" showing file header and data.

```
FILE  DATE    TIME       HEIGHT   POSITIO    LAI    SEL   DIFN   MTA    SEM SMP
  17  11 SEP  17:09:42   KNEEHI   OMNI       4.14   0.07  0.033   41      0  40

ANGLES 7.000  23.00  38.00  53.00  68.00
CNTCT# 3.330  2.905  2.369  2.171  1.666
STDDEV 0.920  0.709  0.390  0.291  0.134
DISTS  1.008  1.087  1.270  1.662  2.670
GAPS   0.035  0.043  0.050  0.028  0.012

A  1 17:10:01  14.00  10.73  10.26  12.29  12.79
B  2 17:09:54  0.309  0.565  0.395  0.260  0.134
A  3 17:10:01  14.00  10.73  10.26  12.29  12.79
B  4 17:09:57  0.277  1.125  0.489  0.172  0.124
A  5 17:10:01  14.00  10.73  10.26  12.29  12.79
B  6 17:10:00  0.998  0.724  1.136  0.580  0.242
A  7 17:10:01  14.00  10.73  10.26  12.29  12.79
B  8 17:10:03  0.760  0.471  0.669  0.472  0.150
A  9 17:10:01  14.00  10.73  10.26  12.29  12.79
B 10 17:10:06  0.760  0.525  0.641  0.468  0.169
A 11 17:10:01  14.00  10.73  10.26  12.29  12.79
B 12 17:10:09  0.444  0.612  1.268  0.415  0.217
A 13 17:10:17  14.00  10.84  10.20  12.28  12.76
```

**Table A.6: Segment of Digitized Image Temperature File**
Excerpt of image file showing 1-line header and pixel temperature values.

```
FRM#:  75 DATE&TIME:090990 1308 DESC:tree                         RNG:  50 LVL: 0.0
 2537 2549 2533 2549 2553 2549 2537 2557 2541 2549 2549 2553 2553 2545 2537 2545
 2545 2533 2545 2553 2565 2545 2545 2549 2541 2561 2565 2549 2553 2549 2545 2553
 2541 2549 2545 2549 2541 2545 2541 2553 2549 2541 2545 2537 2537 2545 2537 2541
 2553 2553 2537 2541 2557 2557 2537 2545 2545 2553 2553 2545 2537 2553 2565 2541
 2549 2553 2537 2557 2537 2553 2553 2541 2541 2557 2557 2549 2533 2541 2553 2545
 2545 2533 2541 2549 2541 2537 2549 2549 2549 2541 2537 2549 2541 2541 2545 2549
 2537 2549 2541 2537 2553 2553 2541 2549 2541 2549 2529 2561 2533 2533 2525 2541
 2533 2553 2541 2537 2541 2545 2545 2537 2541 2545 2545 2549 2541 2561 2525 2541
 2537 2545 2549 2541 2553 2541 2553 2545 2549 2545 2541 2549 2549 2537 2541 2545
 2541 2549 2549 2541 2541 2549 2537 2541 2545 2541 2549 2549 2553 2541 2553 2557
 2553 2541 2541 2545 2545 2545 2553 2553 2545 2541 2537 2541 2549 2541 2545 2549
 2533 2541 2541 2545 2541 2541 2545 2553 2545 2533 2545 2549 2545 2537 2541 2545
 2541 2549 2533 2545 2541 2541 2545 2545 2541 2549 2541 2545 2533 2541 2549 2541
 2541 2545 2541 2545 2545 2533 2537 2553 2537 2545 2541 2533 2541 2541 2545 2541
 2549 2537 2549 2529 2537 2545 2537 2549 2541 2537 2529 2549 2545 2533 2541 2541
 2537 2533 2545 2533 2541 2537 2529 2541 2549 2549 2545 2549 2545 2537 2525 2733
```

values to the desired scale, and to cause any zero values encountered in the file to be treated as border pixels.

Files for the primary site are broken into three catagories: gap, deciduous, and mixed. Table A.7 lists all files available with gray-level pixel values. Tables A.8 and A.9 list files whose pixel values are expressed as apparent or blackbody-equivalent temperatures, for gap imagery and mixed species imagery, respectively.

### A.5.3 Data Relating to Sample Imagery

Statistics were calculated for selected scene components, including expanses of deciduous vegetation along the forest edge, expanses of coniferous vegetation along the forest edge, a live tree trunk, and a dead tree trunk. These statistics were graphically depicted in Figures 5.23 through 5.36 in the main body of the report.

Data obtained using a spot radiometer provided by Dr. James Smith, NASA/Goddard Space Flight Center, is shown in Table A.10.

Description statistics, Coniferous treeline FED MAC, Maine, 09/90

| FRM | MMDDYY | TIME | #ROW | #COL | MEAN | SDEV | MAX | MIN | VAR | NPIX |
|---|---|---|---|---|---|---|---|---|---|---|
| 061 | 090990 | 1909 | r-69 | c-76 | 12.008 | 0.284 | 13.100 | 11.100 | 0.081 | 5244.000 |
| 068 | 090990 | 2020 | r-52 | c-73 | 11.550 | 0.168 | 12.100 | 11.000 | 0.028 | 3796.000 |
| 075 | 090990 | 2113 | r-52 | c-73 | 11.234 | 0.170 | 11.800 | 10.600 | 0.029 | 3796.000 |
| 082 | 090990 | 2204 | r-52 | c-73 | 10.898 | 0.217 | 11.600 | 10.200 | 0.047 | 3796.000 |
| 089 | 090990 | 2308 | r-52 | c-73 | 10.537 | 0.133 | 11.100 | 10.100 | 0.018 | 3796.000 |
| 096 | 091090 | 0003 | r-52 | c-73 | 10.112 | 0.174 | 11.300 | 09.700 | 0.030 | 3796.000 |
| 103 | 091090 | 0110 | r-52 | c-73 | 09.905 | 0.165 | 10.900 | 09.400 | 0.027 | 3796.000 |
| 110 | 091090 | 0207 | r-62 | c-37 | 10.045 | 0.113 | 10.400 | 09.700 | 0.013 | 2294.000 |
| 117 | 091090 | 0259 | r-62 | c-37 | 09.805 | 0.138 | 10.400 | 09.400 | 0.019 | 2294.000 |
| 138 | 091090 | 0407 | r-62 | c-37 | 09.430 | 0.111 | 09.800 | 09.100 | 0.012 | 2294.000 |
| 145 | 091090 | 0502 | r-62 | c-37 | 10.505 | 0.154 | 11.200 | 10.100 | 0.024 | 2294.000 |
| 152 | 091090 | 0606 | r-62 | c-37 | 10.027 | 0.185 | 10.600 | 09.400 | 0.034 | 2294.000 |
| 159 | 091090 | 0702 | r-62 | c-37 | 10.650 | 0.128 | 11.000 | 10.200 | 0.016 | 2294.000 |
| 167 | 091090 | 0805 | r-62 | c-37 | 11.360 | NaN.0 | 11.600 | 11.100 | -.002 | 2294.000 |

Descriptive statistics, Deciderous treeline, FED MAC, Maine, 09/90

| FRM | MMDDYY | TIME | #ROW | #COL | MEAN | SDEV | MAX | MIN | VAR | NPIX |
|---|---|---|---|---|---|---|---|---|---|---|
| 061 | 090990 | 1909 | r-27 | c-76 | 11.336 | 0.368 | 12.500 | 10.100 | 0.135 | 2052.000 |
| 068 | 090990 | 2020 | r-26 | c-76 | 10.899 | 0.195 | 11.600 | 10.200 | 0.038 | 1976.000 |
| 075 | 090990 | 2113 | r-27 | c-76 | 10.795 | 0.137 | 11.300 | 10.300 | 0.019 | 2052.000 |
| 082 | 090990 | 2204 | r-27 | c-76 | 10.150 | 0.204 | 10.900 | 09.500 | 0.042 | 2052.000 |
| 089 | 090990 | 2308 | r-27 | c-76 | 10.314 | 0.110 | 10.600 | 09.800 | 0.012 | 2052.000 |
| 096 | 091090 | 0003 | r-27 | c-76 | 09.756 | 0.117 | 10.100 | 09.400 | 0.014 | 2052.000 |
| 103 | 091090 | 0110 | r-26 | c-76 | 09.680 | 0.119 | 10.200 | 09.300 | 0.014 | 1976.000 |
| 117 | 091090 | 0259 | r-26 | c-76 | 09.770 | 0.117 | 10.200 | 09.400 | 0.014 | 1976.000 |
| 138 | 091090 | 0407 | r-26 | c-76 | 09.345 | 0.126 | 09.900 | 08.900 | 0.016 | 1976.000 |
| 145 | 091090 | 0502 | r-26 | c-76 | 10.569 | 0.207 | 11.200 | 09.800 | 0.043 | 1976.000 |
| 152 | 091090 | 0606 | r-26 | c-76 | 10.145 | 0.260 | 11.100 | 09.000 | 0.067 | 1976.000 |
| 159 | 091090 | 0702 | r-26 | c-76 | 10.784 | 0.189 | 11.700 | 10.000 | 0.036 | 1976.000 |
| 167 | 091090 | 0805 | r-27 | c-76 | 11.408 | NaN.0 | 11.600 | 11.200 | -.001 | 2052.000 |

**Table A.7: Digitized Thermal Image Data Files**
Digitized versions of infrared imagery, with gray-scale pixel values (0-255), from KRC Primary Site, NEF, Howland, Maine.

| FILENAME | DATE | TIME | DESCRIPTION | RANGE | AMBIENT | HEATED |
|---|---|---|---|---|---|---|
| a07.a | 090990 | 1114 | MIXED | 20 | | |
| a08.a | 090990 | 1114 | BLACK BODY | 20 | 17.6 | 27.6 |
| a12.a | 090990 | 1114 | MIXED | 50 | | |
| a19.a | 090990 | 1209 | MIXED | 50 | | |
| a20.a | 090990 | 1210 | BLACK BODY | 50 | 18.2 | 28.2 |
| a26.a | 090990 | 1433 | MIXED | 10 | | |
| a27.a | 090990 | 1434 | BLACK BODY | 10 | 20 | 26.4 |
| a33.a | 090990 | 1542 | MIXED | 10 | | |
| a34.a | 090990 | 1543 | BLACK BODY | 10 | 20.2 | 25.1 |
| a38.a | 090990 | 1546 | MIXED | 10 | | |
| a42.a | 090990 | 1659 | MIXED | 5 | | |
| a43.a | 090990 | 1700 | BLACK BODY | 5 | 17.2 | 23.3 |
| a51.a | 090990 | 1828 | MIXED | 10 | | |
| a52.a | 090990 | 1830 | BLACK BODY | 10 | 14.3 | 17.5 |
| a58.a | 090990 | 1905 | BLACK BODY | 10 | 12.3 | 15.3 |
| a59.a | 090990 | 1906 | DECID | 10 | | |
| a60.a | 090990 | 1906 | GAP | 10 | | |
| a61.a | 090990 | 1909 | MIXED | 10 | | |
| a62.a | 090990 | 1910 | BLACK BODY | 10 | 12.2 | 15.0 |
| a63.a | 090990 | 2010 | BLACK BODY | 5 | 12.1 | 13.4 |
| a64.a | 090990 | 2014 | GAP | 5 | | |
| a65.a | 090990 | 2016 | BLACK BODY | 5 | 12.0 | 13.4 |
| a66.a | 090990 | 2018 | DECID | 5 | | |
| a67.a | 090990 | 2019 | GAP | 5 | | |
| a68.a | 090990 | 2020 | MIXED | 5 | | |
| a69.a | 090990 | 2020 | BLACK BODY | 5 | 11.9 | 13.4 |
| a70.a | 090990 | 2103 | BLACK BODY | 5 | 11.9 | 13.4 |
| a71.a | 090990 | 2104 | GAP | 5 | | |
| a72.a | 090990 | 2108 | BLACK BODY | 5 | 11.9 | 13.4 |
| a73.a | 090990 | 2110 | DECID | 5 | | |
| a74.a | 090990 | 2112 | GAP | 5 | | |
| a75.a | 090990 | 2113 | MIXED | 5 | | |
| a76.a | 090990 | 2114 | BLACK BODY | 5 | 11.8 | 13.4 |
| a77.a | 090990 | 2159 | BLACK BODY | 10 | 10.5 | 13.4 |
| a78.a | 090990 | 2200 | GAP | 10 | | |
| a79.a | 090990 | 2202 | BLACK BODY | 10 | 10.5 | 13.4 |
| a80.a | 090990 | 2203 | DECID | 10 | | |
| A81.A | 090990 | 2204 | GAP | 10 | | |
| a82.a | 090990 | 2204 | MIXED | 10 | | |
| a83.a | 090990 | 2205 | BLACK BODY | 10 | 10.5 | 13.4 |
| a84.a | 090990 | 2259 | BLACK BODY | 5 | 10.9 | 12.5 |
| a85.a | 090990 | 2300 | GAP | 5 | | |
| a86.a | 090990 | 2303 | BLACK BODY | 5 | 10.9 | 12.5 |
| a87.a | 090990 | 2306 | DECIDEROUS | 5 | | |
| a88.a | 090990 | 2307 | GAP | 5 | | |

Table A.7: Digitized Thermal Image Data Files, P. 2 of 7

| FILENAME | DATE | TIME | DESCRIPTION | RANGE | AMBIENT | HEATED |
|---|---|---|---|---|---|---|
| a89.a | 090990 | 2308 | MIXED | 5 | | |
| a90.a | 090990 | 2309 | BLACK BODY | 5 | 10.9 | 12.6 |
| a91.a | 090990 | 2359 | BLACK BODY | 5 | 10.9 | 12.6 |
| a92.a | 090990 | 2359 | GAP | 5 | | |
| a93.a | 091090 | 0000 | BLACK BODY | 5 | 10.6 | 12.3 |
| a94.a | 091090 | 0001 | DECIDEROUS | 5 | | |
| a95.a | 091090 | 0002 | GAP | 5 | | |
| a96.a | 091090 | 0003 | MIXED | 5 | | |
| a97.a | 091090 | 0004 | BLACK BODY | 5 | 10.6 | 12.3 |
| a98.a | 091090 | 0103 | BLACK BODY | 5 | 10.6 | 12.4 |
| a99.a | 091090 | 0104 | GAP | 5 | | |
| a100.a | 091090 | 0107 | BLACK BODY | 5 | 10.7 | 12.3 |
| a101.a | 091090 | 0108 | DECIDEROUS | 5 | | |
| a102.a | 091090 | 0109 | GAP | 5 | | |
| a103.a | 091090 | 0110 | MIXED | 5 | | |
| a104.a | 091090 | 0111 | BLACK BODY | 5 | 10.7 | 12.3 |
| a105.a | 091090 | 0200 | BLACK BODY | 5 | 10.6 | 12.4 |
| a106.a | 091090 | 0201 | GAP | 5 | | |
| a107.a | 091090 | 0204 | BLACK BODY | 5 | 10.6 | 12.4 |
| a108.a | 091090 | 0206 | DECIDEROUS | 5 | | |
| a109.a | 091090 | 0206 | GAP | 5 | | |
| a110.a | 091090 | 0207 | MIXED | 5 | | |
| a111.a | 091090 | 0208 | BLACK BODY | 5 | 10.6 | 12.3 |
| a112.a | 091090 | 0254 | BLACK BODY | 5 | 10.7 | 12.6 |
| a113.a | 091090 | 0255 | GAP | 5 | | |
| a114.a | 091090 | 0256 | BLACK BODY | 5 | 10.7 | 12.5 |
| a115.a | 091090 | 0257 | DECIDEROUS | 5 | | |
| a116.a | 091090 | 0258 | GAP | 5 | | |
| a117.a | 091090 | 0259 | MIXED | 5 | | |
| a118.a | 091090 | 0300 | BLACK BODY | 5 | 10.7 | 12.5 |
| a133.a | 091090 | 400 | BLACK BODY | 5 | 10.8 | 12.4 |
| a134.a | 091090 | 401 | GAP | 5 | | |
| a135.a | 091090 | 404 | BLACK BODY | 5 | 10.7 | 12.6 |
| a136.a | 091090 | 406 | DECIDUOUS | 5 | | |
| a137.a | 091090 | 406 | GAP | 5 | | |
| a138.a | 091090 | 407 | MIXED | 5 | | |
| a139.a | 091090 | 408 | BLACK BODY | 5 | 10.6 | 12.5 |
| a140.a | 091090 | 457 | BLACK BODY | 5 | 11.3 | 12.6 |
| a141.a | 091090 | 457 | GAP | 5 | | |
| a142.a | 091090 | 459 | BLACK BODY | 5 | 11.3 | 12.6 |
| a143.a | 091090 | 500 | DECIDUOUS | 5 | | |
| a144.a | 091090 | 501 | GAP | 5 | | |
| a145.a | 091090 | 502 | MIXED | 5 | | |
| a146.a | 091090 | 502 | BLACK BODY | 5 | 11.5 | 12.6 |
| a147.a | 091090 | 558 | BLACK BODY | 5 | 11.7 | 12.6 |
| a148.a | 091090 | 600 | GAP | 5 | | |

Table A.7: Digitized Thermal Image Data Files, P. 3 of 7

| FILENAME | DATE | TIME | DESCRIPTION | RANGE | AMBIENT | HEATED |
|---|---|---|---|---|---|---|
| a149.a | 091090 | 603 | BLACK BODY | 5 | 11.6 | 12.5 |
| a150.a | 091090 | 604 | DECIDUOUS | 5 | | |
| a151.a | 091090 | 605 | GAP | 5 | | |
| a152.a | 091090 | 606 | MIXED | 5 | | |
| a153.a | 091090 | 607 | BLACK BODY | 5 | 11.7 | 12.6 |
| a154.a | 091090 | 657 | BLACK BODY | 5 | 12.0 | 13.5 |
| a155.a | 091090 | 658 | GAP | 5 | | |
| a156.a | 091090 | 700 | BLACK BODY | 5 | 12.0 | 13.5 |
| a157.a | 091090 | 701 | DECIDUOUS | 5 | | |
| a158.a | 091090 | 701 | GAP | 5 | | |
| a159.a | 091090 | 702 | MIXED | 5 | | |
| a160.a | 091090 | 702 | BLACK BODY | 5 | 12.0 | 13.5 |
| a161.a | 091090 | 703 | VISIBLE SCAN | 5 | | |
| a162.a | 091090 | 758 | BLACK BODY | 5 | 12.3 | 16.7 |
| a163.a | 091090 | 759 | GAP | 5 | | |
| a164.a | 091090 | 802 | BLACK BODY | 5 | 12.4 | 16.4 |
| a165.a | 091090 | 803 | DECIDUOUS | 5 | | |
| a166.a | 091090 | 804 | GAP | 5 | | |
| a167.a | 091090 | 805 | MIXED | 5 | | |
| a168.a | 091090 | 806 | BLACK BODY | 5 | 12.4 | 16.0 |
| a169.a | 091090 | 910 | BLACK BODY | 5 | 13.1 | 14.3 |
| a170.a | 091090 | 912 | GAP | 5 | | |
| a171.a | 091090 | 917 | BLACK BODY | 5 | 13.2 | 14.3 |
| a172.a | 091090 | 918 | DECIDUOUS | 5 | | |
| a173.a | 091090 | 919 | GAP | 5 | | |
| a174.a | 091090 | 919 | MIXED | 5 | | |
| a175.a | 091090 | 920 | BLACK BODY | 5 | 13.2 | 14.3 |
| a176.a | 091090 | 1002 | BLACK BODY | 5 | 13.7 | 14.9 |
| a177.a | 091090 | 1003 | GAP | 5 | | |
| a178.a | 091090 | 1005 | BLACK BODY | 5 | 13.8 | 14.8 |
| a179.a | 091090 | 1006 | DECIDUOUS | 5 | | |
| a180.a | 091090 | 1007 | GAP | 5 | | |
| a181.a | 091090 | 1008 | MIXED | 5 | | |
| a182.a | 091090 | 1009 | BLACK BODY | 5 | 13.8 | 14.8 |
| a183.a | 091090 | 1104 | BLACK BODY | 5 | 14.3 | 15.4 |
| a184.a | 091090 | 1105 | GAP | 5 | | |
| a185.a | 091090 | 1107 | BLACK BODY | 5 | 14.4 | 15.4 |
| a186.a | 091090 | 1108 | DECIDUOUS | 5 | | |
| a187.a | 091090 | 1108 | GAP | 5 | | |
| a188.a | 091090 | 1109 | MIXED | 5 | | |
| a189.a | 091090 | 1110 | BLACK BODY | 5 | 14.4 | 15.4 |
| a190.a | 091090 | 1115 | DECIDUOUS VISUAL | 5 | | |
| a191.a | 091090 | 1115 | GAP VISUAL | 5 | | |
| a192.a | 091090 | 1115 | MIXED VISUAL | 5 | | |
| a193.a | 091090 | 1240 | BLACK BODY | 5 | 15.4 | 19.4 |
| a194.a | 091090 | 1241 | GAP | 5 | | |
| a195.a | 091090 | 1244 | BLACK BODY | 5 | 15.3 | 19.4 |
| a196.a | 091090 | 1245 | DECIDUOUS | 5 | | |

Table A.7: Digitized Thermal Image Data Files, P. 4 of 7

| FILENAME | DATE | TIME | DESCRIPTION | RANGE | AMBIENT | HEATED |
|---|---|---|---|---|---|---|
| a197.a | 091090 | 1246 | GAP | 5 | | |
| a198.a | 091090 | 1247 | MIXED | 5 | | |
| a199.a | 091090 | 1247 | BLACK BODY | 5 | 15.4 | 19.2 |
| a200.a | 091090 | 1406 | BLACK BODY | 5 | 15.7 | 17.9 |
| a201.a | 091090 | 1407 | GAP | 5 | | |
| a202.a | 091090 | 1408 | GAP VISUAL | | 5 | |
| a203.a | 091090 | 1410 | BLACK BODY | 5 | 15.6 | 17.8 |
| a204.a | 091090 | 1412 | DECIDUOUS | 5 | | |
| a205.a | 091090 | 1413 | GAP | 5 | | |
| a206.a | 091090 | 1413 | MIXED | 5 | | |
| a207.a | 091090 | 1414 | BLACK BODY | 5 | 15.6 | 17.8 |
| a208.a | 091090 | 1420 | DECIDUOUS VISUAL | 5 | | |
| a209.a | 091090 | 1420 | GAP VISUAL | 5 | | |
| a210.a | 091090 | 1422 | MIXED VISUAL | 5 | | |
| a211.a | 091090 | 1555 | BLACK BODY | 5 | 16.2 | 17.5 |
| a212.a | 091090 | 1556 | GAP | 5 | | |
| a213.a | 091090 | 1558 | BLACK BODY | 5 | 16.2 | 17.5 |
| a214.a | 091090 | 1558 | DECIDUOUS | 5 | | |
| a215.a | 091090 | 1559 | GAP | 5 | | |
| a216.a | 091090 | 1600 | MIXED | 5 | | |
| a217.a | 091090 | 1601 | BLACK BODY | 5 | 16.4 | 17.7 |
| a218.a | 091090 | 1744 | BLACK BODY | 5 | 16.9 | 18.4 |
| a218b. | 091090 | 1745 | GAP | 5 | | |
| a219.a | 091090 | 1747 | BLACK BODY | 5 | 16.7 | 18.4 |
| a220.a | 091090 | 1748 | DECIDUOUS | 5 | | |
| a221.a | 091090 | 1749 | GAP | 5 | | |
| a222.a | 091090 | 1752 | MIXED | 5 | | |
| a223.a | 091090 | 1753 | BLACK BODY | 5 | 16.6 | 18.3 |
| a224.a | 091090 | 1756 | BLACK BODY | 5 | 16.4 | 18.2 |
| a225.a | 091090 | 1757 | DECIDUOUS | 5 | | |
| a226.a | 091090 | 1758 | GAP | 5 | | |
| a227.a | 091090 | 1759 | MIXED | 5 | | |
| a228.a | 091090 | 1759 | BLACK BODY | 5 | 16.4 | 18.2 |
| a229.a | 091090 | 1818 | BLACK BODY | 5 | 15.9 | 17.6 |
| a230.a | 091090 | 1820 | GAP | 5 | | |
| a231.a | 091090 | 1821 | BLACK BODY | 5 | 15.8 | 17.5 |
| a232.a | 091090 | 1822 | DECIDUOUS | 5 | | |
| a233.a | 091090 | 1823 | GAP | 5 | | |
| a234.a | 091090 | 1823 | MIXED | 5 | | |
| a235.a | 091090 | 1824 | BLACK BODY | 5 | 15.8 | 17.5 |
| a236.a | 091090 | 1826 | DECIDUOUS VISUAL | 5 | | |
| a237.a | 091090 | 1827 | GAP VISUAL | 5 | | |
| a238.a | 091090 | 1828 | MIXED VISUAL | 5 | | |
| a239.a | 091090 | 1837 | BLACK BODY | 10 | 14.9 | 17 |
| a240.a | 091090 | 1838 | GAP | 10 | | |
| a241.a | 091090 | 1842 | BLACK BODY | 5 | 14.6 | 16.8 |
| a242.a | 091090 | 1843 | DECIDUOUS | 5 | | |
| a243.a | 091090 | 1843 | GAP | 5 | | |

Table A.7: Digitized Thermal Image Data Files, P. 5 of 7

| FILENAME | DATE | TIME | DESCRIPTION | RANGE | AMBIENT | HEATED |
|---|---|---|---|---|---|---|
| a244.a | 091090 | 1844 | MIXED | 5 | | |
| a245.a | 091090 | 1845 | BLACK BODY | 5 | 14.4 | 16.8 |
| a246.a | 091090 | 1854 | BLACK BODY | 10 | 13.8 | 16.4 |
| a247.a | 091090 | 1855 | GAP | 10 | | |
| a310.a | 091190 | 256 | BLACK BODY | 5 | 13.0 | 15.5 |
| a311.a | 091190 | 258 | GAP | 5 | | |
| a312.a | 091190 | 300 | BLACK BODY | 5 | 12.9 | 15.5 |
| a313.a | 091190 | 300 | DECIDUOUS | 5 | | |
| a314.a | 091190 | 301 | GAP | 5 | | |
| a315.a | 091190 | 302 | MIXED | 5 | | |
| a316.a | 091190 | 302 | BLACK BODY | 5 | 12.9 | 15.5 |
| a317.a | 091190 | 358 | BLACK BODY | 5 | 13.1 | 15.6 |
| a318.a | 091190 | 359 | GAP | 5 | | |
| a319.a | 091190 | 401 | BLACK BODY | 5 | 13.1 | 15.6 |
| a320.a | 091190 | 402 | DECIDUOUS | 5 | | |
| a321.a | 091190 | 402 | GAP | 5 | | |
| a322.a | 091190 | 403 | MIXED | 5 | | |
| a323.a | 091190 | 404 | BLACK BODY | 5 | 13.1 | 15.5 |
| a324.a | 091190 | 459 | BLACK BODY | 5 | 13.2 | 15.5 |
| a325.a | 091190 | 500 | GAP | 5 | | |
| a326.a | 091190 | 502 | BLACK BODY | 5 | 13.2 | 15.4 |
| a327.a | 091190 | 502 | DECIDUOUS | 5 | | |
| a328.a | 091190 | 503 | GAP | 5 | | |
| a329.a | 091190 | 504 | MIXED | 5 | | |
| a330.a | 091190 | 504 | BLACK BODY | 5 | 13.2 | 15.4 |
| a331.a | 091190 | 608 | BLACK BODY | 5 | 13.0 | 15.4 |
| a332.a | 091190 | 609 | GAP | 5 | | |
| a333.a | 091190 | 612 | BLACK BODY | 5 | 13.0 | 15.4 |
| a334.a | 091190 | 613 | DECIDUOUS | 5 | | |
| a335.a | 091190 | 614 | GAP | 5 | | |
| a336.a | 091190 | 614 | MIXED | 5 | | |
| a337.a | 091190 | 615 | BLACK BODY | 5 | 13.0 | 15.4 |
| a338.a | 091190 | 658 | BLACK BODY | 5 | 13.2 | 15.6 |
| a339.a | 091190 | 659 | GAP | 5 | | |
| a340.a | 091190 | 700 | BLACK BODY | 5 | 13.2 | 15.6 |
| a341.a | 091190 | 701 | DECIDUOUS | 5 | | |
| a342.a | 091190 | 701 | GAP | 5 | | |
| a343.a | 091190 | 702 | MIXED | 5 | | |
| a344.a | 091190 | 702 | BLACK BODY | 5 | 13.2 | 15.6 |
| a345.a | 091190 | 800 | BLACK BODY | 5 | 14.1 | 15.7 |
| a346.a | 091190 | 802 | GAP | 5 | | |
| a347.a | 091190 | 804 | BLACK BODY | 5 | 14.2 | 15.7 |
| a348.a | 091190 | 806 | DECIDUOUS | 5 | | |
| a349.a | 091190 | 807 | GAP | 5 | | |
| a350.a | 091190 | 808 | MIXED | 5 | | |
| a351.a | 091190 | 809 | MIXED | 5 | | |
| a352.a | 091190 | 901 | BLACK BODY | 5 | 15.3 | 16.7 |
| a353.a | 091190 | 907 | GAP | 5 | | |
| a354.a | 091190 | 904 | BLACK BODY | 5 | 15.3 | 16.7 |

Table A.7: Digitized Thermal Image Data Files, P. 6 of 7

| | | | | | | |
|---|---|---|---|---|---|---|
| a355.a | 091190 | 905 | BLACK BODY | 10 | 15.8 | 16.9 |
| a356.a | 091190 | 906 | DECIDUOUS | 10 | | |
| a357.a | 091190 | 908 | BLACK BODY | 20 | 16.7 | 17.4 |
| a358.a | 091190 | 909 | DECIDUOUS | 20 | | |
| a359.a | 091190 | 910 | GAP | 20 | | |
| a360.a | 091190 | 910 | MIXED | 20 | | |
| a361.a | 091190 | 911 | BLACK BODY | 20 | 17.1 | 17.6 |
| a362.a | 091190 | 1000 | BLACK BODY | 20 | 20.2 | 25.2 |
| a363.a | 091190 | 1002 | GAP | 20 | | |
| a364.a | 091190 | 1004 | BLACK BODY | 20 | 20.0 | 25.1 |
| a365.a | 091190 | 1005 | DECIDUOUS | 20 | | |
| a366.a | 091190 | 1005 | GAP | 20 | | |
| a367.a | 091190 | 1006 | MIXED | 20 | | |
| a368.a | 091190 | 1007 | BLACK BODY | 20 | 19.6 | 25.0 |
| a369.a | 091190 | 1055 | BLACK BODY | 20 | 20.1 | 26.0 |
| a370.a | 091190 | 1056 | GAP | 20 | | |
| a371.a | 091190 | 1058 | BLACK BODY | 20 | 20.6 | 26.3 |
| a372.a | 091190 | 1059 | DECIDUOUS | 20 | | |
| a373.a | 091190 | 1059 | GAP | 20 | | |
| a374.a | 091190 | 1100 | MIXED | 20 | | |
| a375.a | 091190 | 1101 | BLACK BODY | 20 | 20.9 | 26.7 |
| a376.a | 091190 | 1135 | BLACK BODY | 20 | 19.6 | 28.2 |
| a377.a | 091190 | 1137 | GAP | 20 | | |
| a378.a | 091190 | 1138 | BLACK BODY | 20 | 20.3 | 28.7 |
| a379.a | 091190 | 1139 | DECIDUOUS | 20 | | |
| a380.a | 091190 | 1140 | GAP | 20 | | |
| a381.a | 091190 | 1141 | MIXED | 20 | | |
| a382.a | 091190 | 1144 | BLACK BODY | 20 | 21.5 | 29.4 |
| a383.a | 091190 | 1144 | DECIDUOUS | 20 | | |
| a384.a | 091190 | 1147 | MIXED | 20 | | |
| a385.a | 091190 | 1148 | BLACK BODY | 20 | 21.0 | 29.5 |
| a386.a | 091190 | 1149 | GAP | 20 | | |
| a387.a | 091190 | 1202 | BLACK BODY | 20 | 21.8 | 30.9 |
| a388.a | 091190 | 1203 | DECIDUOUS | 20 | | |
| a389.a | 091190 | 1203 | GAP | 20 | | |
| a390.a | 091190 | 1205 | MIXED | 20 | | |
| a391.a | 091190 | 1205 | BLACK BODY | 20 | 21.9 | 31.3 |
| a392.a | 091190 | 1207 | MIXED | 20 | | |
| a393.a | 091190 | 1208 | GAP | 20 | | |
| a394.a | 091190 | 1208 | DECIDUOUS | 20 | | |
| a395.a | 091190 | 1213 | BLACK BODY | 20 | 22.6 | 32.4 |
| a396.a | 091190 | 1214 | DECIDUOUS | 20 | | |
| a397.a | 091190 | 1215 | GAP | 20 | | |
| a398.a | 091190 | 1216 | MIXED | 20 | | |
| a399.a | 091190 | 1217 | BLACK BODY | 20 | 22.1 | 32.0 |
| a400.a | 091190 | 1226 | BLACK BODY | 20 | 21.7 | 31.9 |
| a401.a | 091190 | 1227 | DECIDUOUS | 20 | | |

Table A.7: Digitized Thermal Image Data Files, P. 7 of 7

| | | | | | | |
|---|---|---|---|---|---|---|
| a402.a | 091190 | 1229 | GAP | 20 | | |
| a403.a | 091190 | 1230 | MIXED | 20 | | |
| a404.a | 091190 | 1259 | BLACK BODY | 20 | 18.5 | 28.8 |
| a405.a | 091190 | 1259 | DECIDUOUS | 20 | | |
| a406.a | 091190 | 1300 | GAP | 20 | | |
| a407.a | 091190 | 1301 | MIXED | 20 | | |
| a408.a | 091190 | 1302 | BLACK BODY | 20 | 19.1 | 28.9 |
| a409.a | 091190 | 1311 | BLACK BODY | 20 | 19.4 | 28.8 |
| a410.a | 091190 | 1313 | DECIDUOUS | 20 | | |
| a411.a | 091190 | 1314 | GAP | 20 | | |
| a412.a | 091190 | 1315 | MIXED | 20 | | |
| a413.a | 091190 | 1319 | BLACK BODY | 20 | 19.7 | 29.2 |
| a414.a | 091190 | 1319 | DECIDUOUS | 20 | | |
| a415.a | 091190 | 1320 | GAP | 20 | | |
| a416.a | 091190 | 1322 | BLACK BODY | 20 | 20.9 | 30.2 |
| a417.a | 091190 | 1322 | MIXED | 20 | | |
| a418.a | 091190 | 1342 | BLACK BODY | 20 | 21.6 | 31.9 |
| a419.a | 091190 | 1343 | DECIDUOUS | 20 | | |
| a420.a | 091190 | 1344 | BLACK BODY | 20 | 21.9 | 32.4 |
| a421.a | 091190 | 1345 | GAP | 20 | | |
| a422.a | 091190 | 1346 | MIXED | 20 | | |
| a423.a | 091190 | 1351 | BLACK BODY | 20 | 21.8 | 32.4 |
| a424.a | 091190 | 1418 | BLACK BODY | 20 | 21.6 | 32.4 |

**Table A.8: Thermal Image Data Files of Forest Gap**
Infrared imagery, with pixel values expressed as apparent or blackbody-equivalent temperatures, of forest gap area, KRC Primary Site, NEF, Howland, Maine.

| FILENAME | DATE | TIME | DESCRIPTION | RANGE |
|---|---|---|---|---|
| t163 | 091090 | 759 | GAP | 5 |
| t166 | 091090 | 804 | GAP | 5 |
| t170 | 091090 | 912 | GAP | 5 |
| t173 | 091090 | 919 | GAP | 5 |
| t177 | 091090 | 1003 | GAP | 5 |
| t180 | 091090 | 1007 | GAP | 5 |
| t184 | 091090 | 1105 | GAP | 5 |
| t187 | 091090 | 1108 | GAP | 5 |
| t194 | 091090 | 1241 | GAP | 5 |
| t197 | 091090 | 1246 | GAP | 5 |
| t201 | 091090 | 1407 | GAP | 5 |
| t205 | 091090 | 1413 | GAP | 5 |
| t212 | 091090 | 1556 | GAP | 5 |
| t215 | 091090 | 1559 | GAP | 5 |
| t221 | 091090 | 1749 | GAP | 5 |
| t226 | 091090 | 1758 | GAP | 5 |
| t230 | 091090 | 1820 | GAP | 5 |
| t233 | 091090 | 1823 | GAP | 5 |
| t240 | 091090 | 1838 | GAP | 10 |
| t243 | 091090 | 1843 | GAP | 5 |
| t247 | 091090 | 1855 | GAP | 10 |
| t250 | 091090 | 1900 | GAP | 5 |
| t254 | 091090 | 1940 | GAP | 5 |
| t257 | 091090 | 1943 | GAP | 5 |
| t261 | 091090 | 2003 | GAP | 5 |
| t264 | 091090 | 2006 | GAP | 5 |
| t268 | 091090 | 2058 | GAP | 5 |
| t271 | 091090 | 2102 | GAP | 5 |
| t276 | 091090 | 2159 | GAP | 5 |
| t279 | 091090 | 2203 | GAP | 5 |
| t283 | 091090 | 2301 | GAP | 5 |
| t286 | 091090 | 2304 | GAP | 5 |
| t290 | 091190 | 0001 | GAP | 5 |
| t293 | 091190 | 0004 | GAP | 5 |
| t297 | 091190 | 0058 | GAP | 5 |
| t300 | 091190 | 0102 | GAP | 5 |
| t304 | 091190 | 0201 | GAP | 5 |
| t307 | 091190 | 0204 | GAP | 5 |
| t311 | 091190 | 258 | GAP | 5 |
| t314 | 091190 | 301 | GAP | 5 |
| t318 | 091190 | 359 | GAP | 5 |
| t321 | 091190 | 402 | GAP | 5 |
| t325 | 091190 | 500 | GAP | 5 |
| t328 | 091190 | 503 | GAP | 5 |

Table A.8: Thermal Image Data Files of Forest Gap, P. 2 of 2

| | | | | |
|---|---|---|---|---|
| t332 | 091190 | 609 | GAP | 5 |
| t335 | 091190 | 614 | GAP | 5 |
| t339 | 091190 | 659 | GAP | 5 |
| t342 | 091190 | 701 | GAP | 5 |
| t346 | 091190 | 802 | GAP | 5 |
| t349 | 091190 | 807 | GAP | 5 |
| t353 | 091190 | 907 | GAP | 5 |
| t359 | 091190 | 910 | GAP | 20 |
| t363 | 091190 | 1002 | GAP | 20 |
| t366 | 091190 | 1005 | GAP | 20 |
| t370 | 091190 | 1056 | GAP | 20 |
| t373 | 091190 | 1059 | GAP | 20 |
| t377 | 091190 | 1137 | GAP | 20 |
| t380 | 091190 | 1140 | GAP | 20 |
| t386 | 091190 | 1149 | GAP | 20 |
| t389 | 091190 | 1203 | GAP | 20 |
| t393 | 091190 | 1208 | GAP | 20 |
| t402 | 091190 | 1229 | GAP | 20 |
| t406 | 091190 | 1300 | GAP | 20 |
| t411 | 091190 | 1314 | GAP | 20 |
| t415 | 091190 | 1320 | GAP | 20 |

**Table A.9: Thermal Image Data Files of Mixed Species Tree Canopy**
Infrared imagery, with pixel values expressed as apparent or blackbody-equivalent temperatures, of forest gap area, KRC Primary Site, NEF, Howland, Maine.

| FILE NAME | DATE | TIME | COMMENTS |
|---|---|---|---|
| tfm61.mix | 09/09/90 | 1909 | |
| tfm68.mix | 09/09/90 | 2020 | |
| tfm75.mix | 09/09/90 | 2113 | |
| tfm82.mix | 09/09/90 | 2204 | |
| tfm89.mix | 09/09/90 | 2308 | |
| tfm96.mix | 09/10/90 | 0003 | |
| tfm98.mix | 09/10/90 | 0103 | |
| tfm103.mix | 09/10/90 | 0110 | |
| tfm110.mix | 09/10/90 | 0207 | |
| tfm117.mix | 09/10/90 | 0259 | |
| tfm138.mix | 09/10/90 | 0407 | |
| tfm145.mix | 09/10/90 | 0502 | |
| tfm152.mix | 09/10/90 | 0606 | |
| tfm159.mix | 09/10/90 | 0702 | |
| tfm167.mix | 09/10/90 | 0805 | |
| tfm174.mix | 09/10/90 | 0919 | |
| tfm181.mix | 09/10/90 | 1008 | |
| tfm188.mix | 09/10/90 | 1109 | |
| tfm192.mix | 09/10/90 | 1115 | VISUAL |
| tfm198.mix | 09/10/90 | 1247 | |
| tfm206.mix | 09/10/90 | 1413 | |
| tfm210.mix | 09/10/90 | 1422 | VISUAL |
| tfm216.mix | 09/10/90 | 1600 | |
| tfm222.mix | 09/10/90 | 1752 | |
| tfm227.mix | 09/10/90 | 1759 | |
| tfm234.mix | 09/10/90 | 1823 | |
| tfm238.mix | 09/10/90 | 1828 | VISUAL |
| tfm244.mix | 09/10/90 | 1844 | |
| tfm251.mix | 09/10/90 | 1900 | |
| tfm258.mix | 09/10/90 | 1943 | |
| tfm265.mix | 09/10/90 | 2006 | |
| tfm273.mix | 09/10/90 | 2102 | |
| tfm287.mix | 09/10/90 | 2305 | |
| tfm294.mix | 09/11/90 | 0005 | |
| tfm301.mix | 09/11/90 | 0102 | |
| tfm308.mix | 09/11/90 | 0205 | |
| tfm315.mix | 09/11/90 | 0302 | |
| tfm322.mix | 09/11/90 | 0403 | |
| tfm329.mix | 09/11/90 | 0504 | |
| tfm336.mix | 09/11/90 | 0614 | |
| tfm343.mix | 09/11/90 | 0702 | |
| tfm350.mix | 09/11/90 | 0808 | |
| tfm360.mix | 09/11/90 | 0910 | |
| tfm367.mix | 09/11/90 | 1006 | |
| tfm374.mix | 09/11/90 | 1100 | |

**Table A.9: Thermal Image Data Files of Mixed Species Canopy, P. 2 of 2**

| | | |
|---|---|---|
| tfm381.mix | 09/11/90 | 1141 |
| tfm384.mix | 09/11/90 | 1147 |
| tfm390.mix | 09/11/90 | 1205 |
| tfm392.mix | 09/11/90 | 1207 |
| tfm398.mix | 09/11/90 | 1216 |
| tfm403.mix | 09/11/90 | 1230 |
| tfm407.mix | 09/11/90 | 1301 |
| tfm412.mix | 09/11/90 | 1315 |
| tfm417.mix | 09/11/90 | 1322 |

Table A.10: Spot Radiometric Data

SUBJECT: Hand Held IRT Spot Measurements at KRC Primary Site,
NEF, Howland, ME

| VARIABLE | VALUE | VALUE | VALUE | VALUE | VALUE | VALUE | VALUE | VALUE |
|---|---|---|---|---|---|---|---|---|
| DAY (09/90) | 09 | 09 | 09 | 10 | 10 | 10 | 11 | 11 |
| BEGIN TIME | 1630 | 1650 | 1730 | 0925 | 1604 | 1804 | 1152 | 1517 |
| MET STN LOC | 25.3 | 20.3 | 21.0 | 15.3 | 20.2 | 16.8 | -99.9 | 26.9 |
| LOC A | 17.2 | 15.2 | 17.2 | 14.6 | 18.4 | 15.7 | 26.9 | 19.3 |
| LOC B | 17.4 | 15.9 | 16.1 | 13.7 | 17.0 | 15.9 | 31.9 | 22.3 |
| LOC C | 16.6 | 16.1 | 14.5 | 13.7 | 16.4 | 15.8 | 25.7 | 19.2 |
| LOC D | 16.0 | 14.2 | 15.5 | 13.5 | 16.2 | 15.8 | 18.3 | 18.4 |
| MARKER 1 | 21.6 | 17.1 | 15.6 | 15.1 | 19.9 | 16.2 | 27.6 | 28.4 |
| MARKER 2 | 20.9 | 15.8 | 14.2 | 15.5 | 19.0 | 14.9 | 28.7 | 28.1 |
| TREE TRUNK | 17.8 | 16.9 | 16.5 | 13.9 | 16.9 | 16.1 | 38.2 | -99.9 |
| BIRCH/SHADE | -99.9 | -99.9 | -99.9 | -99.9 | -99.9 | 15.7 | -99.9 | 18.1 |
| BIRCH/SUN | -99.9 | -99.9 | -99.9 | 13.9 | 17.2 | 17.5 | 21.8 | 22.5 |
| SPRUCE/SHADE | -99.9 | -99.9 | -99.9 | -99.9 | -99.9 | 16.1 | 17.0 | 18.6 |
| SPRUCE/SUN | -99.9 | -99.9 | -99.9 | -99.9 | 16.5 | -99.9 | 22.9 | 22.3 |
| END TIME | 1634 | 1654 | 1735 | 0930 | 1613 | 1812 | 1157 | 1526 |

NOTE: The value "-99.9" indicates missing data.

# Appendix B

# Single Tree Thermal Imagery and Related Data from FED MAC Field Test

# Single Tree Thermal Imagery and Measurements

## Data to Supplement STAMP Single Tree Analysis

## SWOE/FED MAC Field Test, Howland, Maine

Keweenaw Research Center
Michigan Technological University
Houghton, Michigan

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## LIST OF ILLUSTRATIONS



## LIST OF TABLES

## 1.0. BACKGROUND

Keweenaw Research Center (KRC) participation in the 1990 Forest Ecosystem Dynamics - Multisensor Aircraft Campaign (FED-MAC) project was part of a data collection and exchange effort of the SWOE Thermal Analysis and Measurement Program (STAMP). This work was conducted in order to acquire information useful for model validation, and for establishing the needs and directions of future SWOE measurement programs.

Field test sites, experimental plans, and data acquisition procedures were described in detail in a preliminary report.[1] Supporting measurements, including meteorological data, soil temperature profiles, and spot radiometric data are also presented in the preliminary report.

### 1.1. STAMP Single Tree Analysis

Measurements and analysis of thermal response of a single, isolated tree were planned by SPARTA, Inc. KRC tapes of thermal imagery of the single tree were provided to SPARTA, and specific images were designated for further analysis.[2] The purpose of this report is to describe these specific images and to provide statistical data derived from them, in contribution to the analysis of a tree's thermal response patterns.

## 2.0. SINGLE TREE SITE

### 2.1. Summary Description

The individual aspen tree located near the University of Maine monitoring station was imaged on an hourly basis from 11:20 AM, 9 September, 1990 through 3:05 PM, 11 September, 1990. Calibrated thermal infrared (8-12 $\mu$m) imagery was obtained using an AGEMA Thermovision 880 imaging system. A time-base correction had to be performed to generate imagery that could be digitized and converted to temperature frames.

### 2.2. Description of Thermal Image Files

Thermal imagery depicting the single tree site during specific time periods was digitized using a PC-based Data Translation video frame digitizer. The binary digit frames so created were supplemented by calibration information derived from accompanying blackbody imagery and thermocouple data. The binary digit frames were then converted into calibrated temperature pixel frames. Filenames of the temperature frames requested by SPARTA are listed in Table 2-1.

### 2.3. Thermal Image File Format

Thermal image files described in Table 2-1 are 128x128 pixel ASCII files. They contain a one-line identifying header, followed by records of pixel temperature values of four significant digits, recorded in degrees Kelvin multiplied by ten. The record format is FORMAT(16(16I5)), where each record represents one line of the image, starting with the top line and reading left to right.

[1] "Preliminary Report on Maine Field Test: Thermal Imagery and Supporting Measurements", A.M.L. LaHaie, Keweenaw Research Center, Michigan Technological University, Houghton, Michigan. October, 1990.

[2] From a 23 October, 1990 correspondence with Dr. John R. Hummel, SPARTA, Inc.

## Table 2-1. Single Tree Calibrated Temperature Pixel Frames

The image files described below were selected by SPARTA, Inc., to augment their single tree thermal response analysis. Copies of these files are provided on a 3.5 inch high density disk accompanying this report. Image pairs shown for time periods on 09/11/90 were taken from extended imaging sequences during periods of variable cloudiness, when short-term transitions in temperatures in leaf clusters were of interest.

| Image Filename | Date Mo/Day | Time | Sens. Range | File Description |
|---|---|---|---|---|
| TMA08.A | 09/09 | 1614 | $50°C$. | Single Tree, Lower Half |
| TMA10.A | 09/09 | 1804 | 50 | Single Tree, Lower Half |
| TMA12.A | 09/09 | 2040 | 5 | Single Tree, Lower Half |
| TMA14.A | 09/09 | 2216 | 5 | Single Tree, Lower Half |
| TMA16.A | 09/10 | 0014 | 5 | Single Tree, Lower Half |
| TMA37.A | 09/10 | 1744 | 20 | Single Tree, Lower Half |
| TMA43.A | 09/10 | 1842 | 20 | Single Tree, Lower Half |
| TMA49.A | 09/10 | 1909 | 20 | Single Tree, Lower Half |
| TMA72A.A | 09/11 | 1213 | 50 | Single Tree, Upper Half |
| TMA72A.B | 09/11 | 1213 | 50 | Single Tree, Upper Half |
| TMA78A.A | 09/11 | 1317 | 50 | Single Tree, Upper Half |
| TMA78A.B | 09/11 | 1317 | 50 | Single Tree, Upper Half |

## 3.0. STATISTICS FOR SELECTED IMAGE REGIONS

Descriptive statistics were computed for specific, local regions within the thermal images, including:

1) trunk (lower 11 feet, approximately) of single tree
2) disturbed, mostly bare soil immediately south of single tree
3) ground area (image foreground), short grass cover, west of tree
4) brush (image foreground, right), southwest of tree
5) leaf area - large leaf cluster in center/right (*vis-a-vis* imager perspective) of tree crown - with southern exposure
6) second leaf area - leaf cluster on left side (*vis-a-vis* imager perspective) of tree crown - with northern exposure

### 3.1. Statistics File and Format

Statistics on the tree trunk and ground cover were obtained from frames 8, 10, 12, 14, 16, 37, 43, and 49 (in files TMAnn.A where nn = 08,10,12,14,16,37,43,49, respectively). Leaf area statistics came from pairs of images lifted from the sequences recorded in frames 72 and 78 (files TMA72A.A, TMA72B.A, TMA78A.A, and TMA78B.A). These statistics are shown in Table 3-1, and are also contained in the file FMTREE1.DAT. The contents and format of FMTREE1.DAT are:

FRAME, SEQ, TIME, AREA, NPIX, MEAN, STDDEV, MAX, MIN

FORMAT(I4,I2,1X,I4,I2,I4,4(1X,F5.2))

where:

FRAME Frame number from which statistics computed
SEQ Sequence number, if more than one image with same frame number
TIME Time of day (0000 - 2400) at which imagery recorded
AREA Code for image region, or area, which statistics describe:

1) trunk (lower 11 feet, approximately) of single tree
2) disturbed, mostly bare soil immediately south of single tree
3) ground area (image foreground), short grass cover, west of tree
4) brush (image foreground, right), southwest of tree
5) leaf area - large leaf cluster in center/right (*vis-a-vis* imager perspective) of tree crown - with southern exposure
6) second leaf area - leaf cluster on left side (*vis-a-vis* imager perspective) of tree crown - with northern exposure

NPIX Number of Pixels sample to calculate descriptive statistics
MEAN Arithmetic mean ($^{\circ}C$) for pixel values in specified image region
STDDEV Standard Deviation ($^{\circ}C$) for pixel values in specified image region
MAX Maximum pixel value ($^{\circ}C$) in specified image region
MIN Minimum pixel value ($^{\circ}C$) in specified image region.

### 3.2. Statistics Data Plots

Figure 3-1 through Figure 3-5 graphically depict maximum, mean, and minimum apparent temperatures recorded for the tree trunk, soil, ground area, and brush, respectively, at selected times on 09 September, 1990. Figure 3-6 through Figure 3-10 provides the same information for the same set of areas, at selected times on 10 September, 1990. Statistics for leaf areas are plotted in Figures 3-11 and 3-12.

## Table 3-1. Descriptive Statistics for Selected Image Regions

| FRAME | SEQ | TIME | AREA | NPIX | MEAN | STDDEV | MAX | MIN |
|---|---|---|---|---|---|---|---|---|
| 8 | 1 | 1616 | 1 | 92 | 21.17 | 3.44 | 29.90 | 15.10 |
| 10 | 1 | 1804 | 1 | 92 | 18.33 | 2.92 | 27.60 | 12.00 |
| 12 | 1 | 2041 | 1 | 94 | 12.68 | 0.41 | 13.50 | 11.10 |
| 14 | 1 | 2216 | 1 | 92 | 11.83 | 0.36 | 12.40 | 10.50 |
| 16 | 1 | 0014 | 1 | 92 | 11.44 | 0.26 | 12.3 | 10.8 |
| 37 | 1 | 1744 | 1 | 92 | 11.69 | 2.68 | 18.80 | 7.10 |
| 43 | 1 | 1842 | 1 | 92 | 13.91 | 3.08 | 21.00 | 8.20 |
| 49 | 1 | 1902 | 1 | 94 | 15.93 | 1.68 | 18.70 | 10.30 |
| 8 | 1 | 1616 | 2 | 24 | 32.33 | 3.47 | 39.50 | 27.10 |
| 10 | 1 | 1804 | 2 | 32 | 15.13 | 1.36 | 18.40 | 13.20 |
| 12 | 1 | 2041 | 2 | 24 | 11.05 | 0.31 | 11.40 | 10.30 |
| 14 | 1 | 2216 | 2 | 24 | 10.15 | 0.20 | 10.50 | 9.80 |
| 16 | 1 | 0014 | 2 | 32 | 11.42 | 0.35 | 12,1 | 10.50 |
| 37 | 1 | 1744 | 2 | 24 | 14.59 | 3.26 | 20.30 | 9.30 |
| 43 | 1 | 1842 | 2 | 24 | 7.51 | 2.27 | 10.90 | 4.00 |
| 49 | 1 | 1902 | 2 | 24 | 10.30 | 1.81 | 13.20 | 6.80 |
| 8 | 1 | 1616 | 3 | 25 | 19.29 | 2.17 | 24.70 | 15.50 |
| 10 | 1 | 1804 | 3 | 25 | 13.63 | 1.37 | 16.40 | 10.00 |
| 12 | 1 | 2041 | 3 | 36 | 11.50 | 0.26 | 12.00 | 10.90 |
| 14 | 1 | 2216 | 3 | 30 | 10.37 | 0.18 | 10.70 | 10.00 |
| 16 | 1 | 0014 | 3 | 36 | 11.02 | 0.17 | 11.40 | 10.60 |
| 37 | 1 | 1744 | 3 | 25 | 7.97 | 1.06 | 10.20 | 6.50 |
| 43 | 1 | 1842 | 3 | 25 | 8.25 | 1.12 | 10.40 | 6.00 |
| 49 | 1 | 1902 | 3 | 25 | 8.18 | 1.55 | 11.20 | 4.20 |
| 8 | 1 | 1616 | 4 | 99 | 14.83 | 1.42 | 19.50 | 10.70 |
| 10 | 1 | 1804 | 4 | 99 | 13.62 | 1.53 | 16.40 | 8.00 |
| 12 | 1 | 2041 | 4 | 99 | 11.91 | 0.32 | 12.40 | 10.90 |
| 14 | 1 | 2216 | 4 | 99 | 10.71 | 0.27 | 11.20 | 9.80 |
| 16 | 1 | 0014 | 4 | 99 | 10.99 | 0.14 | 11.30 | 10.50 |
| 37 | 1 | 1744 | 4 | 99 | 5.33 | 0.90 | 7.30 | 2.10 |
| 43 | 1 | 1842 | 4 | 99 | 8.09 | 1.23 | 10.90 | 4.50 |
| 49 | 1 | 1902 | 4 | 99 | 12.45 | 1.08 | 14.70 | 9.50 |

(Continued on Next Page)

**Table 3-1. Descriptive Statistics for Selected Image Regions, Continued**

| FRAME | SEQ | TIME | AREA | NPIX | MEAN | STDDEV | MAX | MIN |
|---|---|---|---|---|---|---|---|---|
| 8 | 1 | 1616 | 5 | 4 | 14.50 | 1.92 | 16.30 | 12.30 |
| 10 | 1 | 1804 | 5 | 6 | 12.60 | 1.57 | 15.20 | 10.80 |
| 12 | 1 | 2041 | 5 | 6 | 12.22 | 0.48 | 12.70 | 11.30 |
| 14 | 1 | 2216 | 5 | 4 | 11.17 | 0.32 | 11.50 | 10.90 |
| 16 | 1 | 0014 | 5 | 6 | 10.98 | 0.30 | 11.20 | 10.60 |
| 37 | 1 | 1744 | 5 | 6 | 7.18 | 0.77 | 8.00 | 6.00 |
| 43 | 1 | 1842 | 5 | 6 | 10.37 | 0.99 | 11.70 | 9.50 |
| 49 | 1 | 1902 | 5 | 9 | 12.18 | 2.23 | 15.60 | 6.40 |
| 72 | 1 | 1213 | 6 | 48 | 7.71 | 2.15 | 11.80 | 2.20 |
| 72 | 2 | 1213 | 6 | 46 | 6.59 | 2.55 | 11.40 | 1.00 |
| 78 | 1 | 1317 | 6 | 46 | 14.54 | 2.90 | 22.20 | 7.40 |
| 78 | 2 | 1317 | 6 | 46 | 15.31 | 2.50 | 20,21 | 7.80 |
| 72 | 1 | 1213 | 7 | 12 | 4.20 | 2.48 | 7.80 | 1.00 |
| 72 | 2 | 1213 | 7 | 6 | 3.27 | 1.42 | 5.00 | 1.40 |
| 78 | 1 | 1317 | 7 | 12 | 12.57 | 2.79 | 16.20 | 8.20 |
| 78 | 2 | 1317 | 7 | 12 | 10.63 | 3.92 | 15.40 | 2.20 |

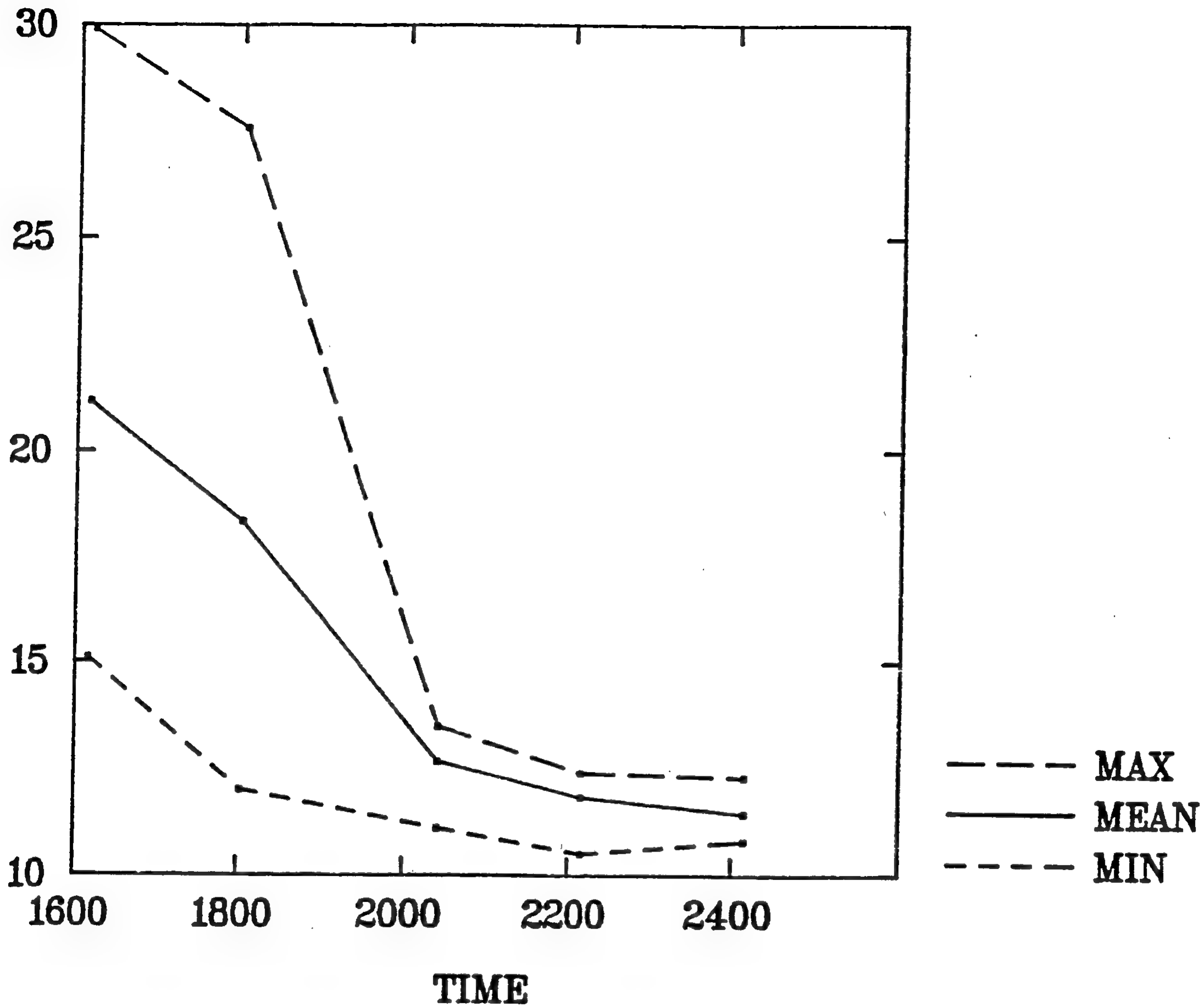



**Figure 3-1. Tree Trunk Apparent Temperature Statistics, 09/09/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the trunk of the single tree are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

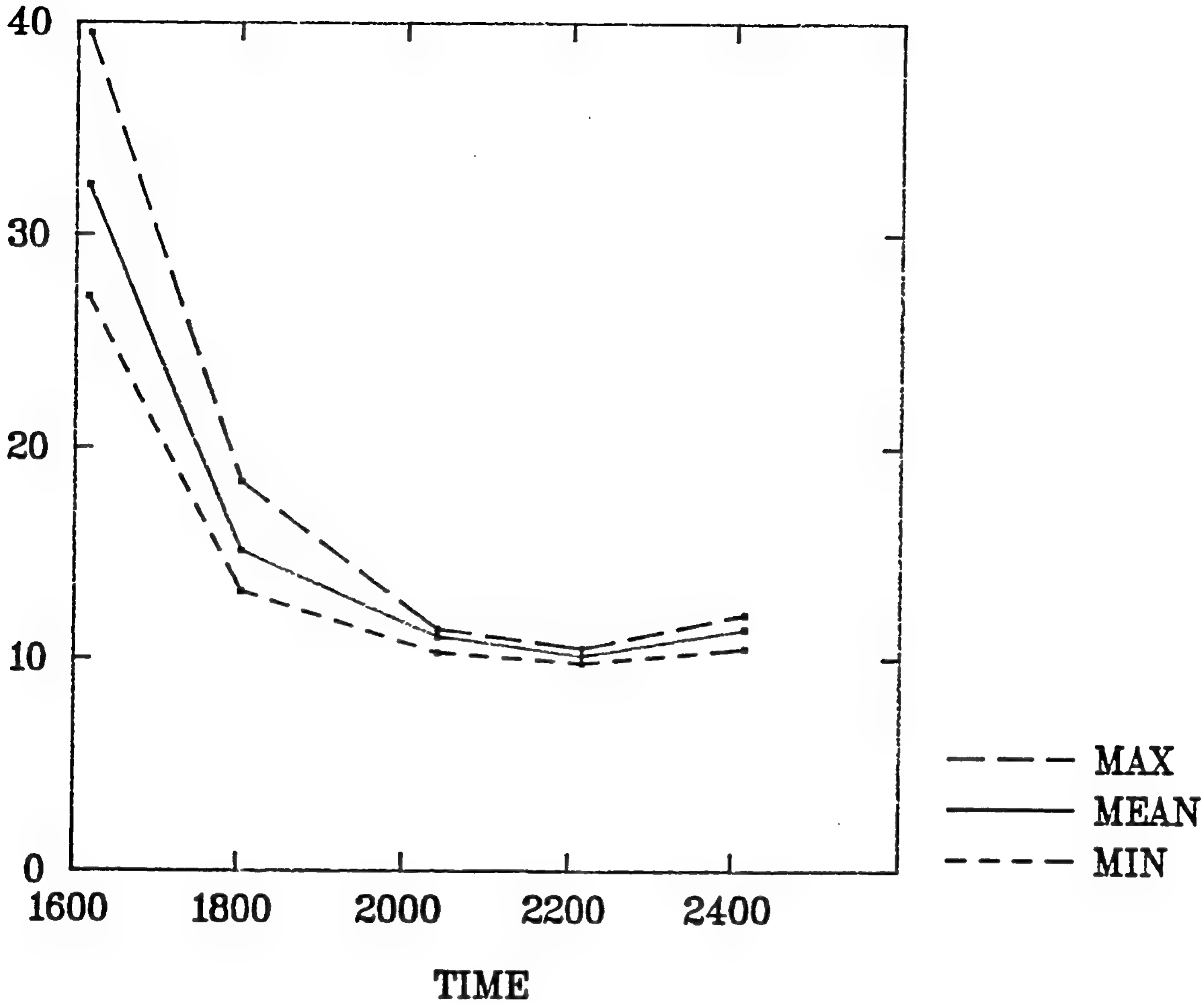



**Figure 3-2. Disturbed Soil Apparent Temperature Statistics, 09/09/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the disturbed soil area immediately to the south of the single tree are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

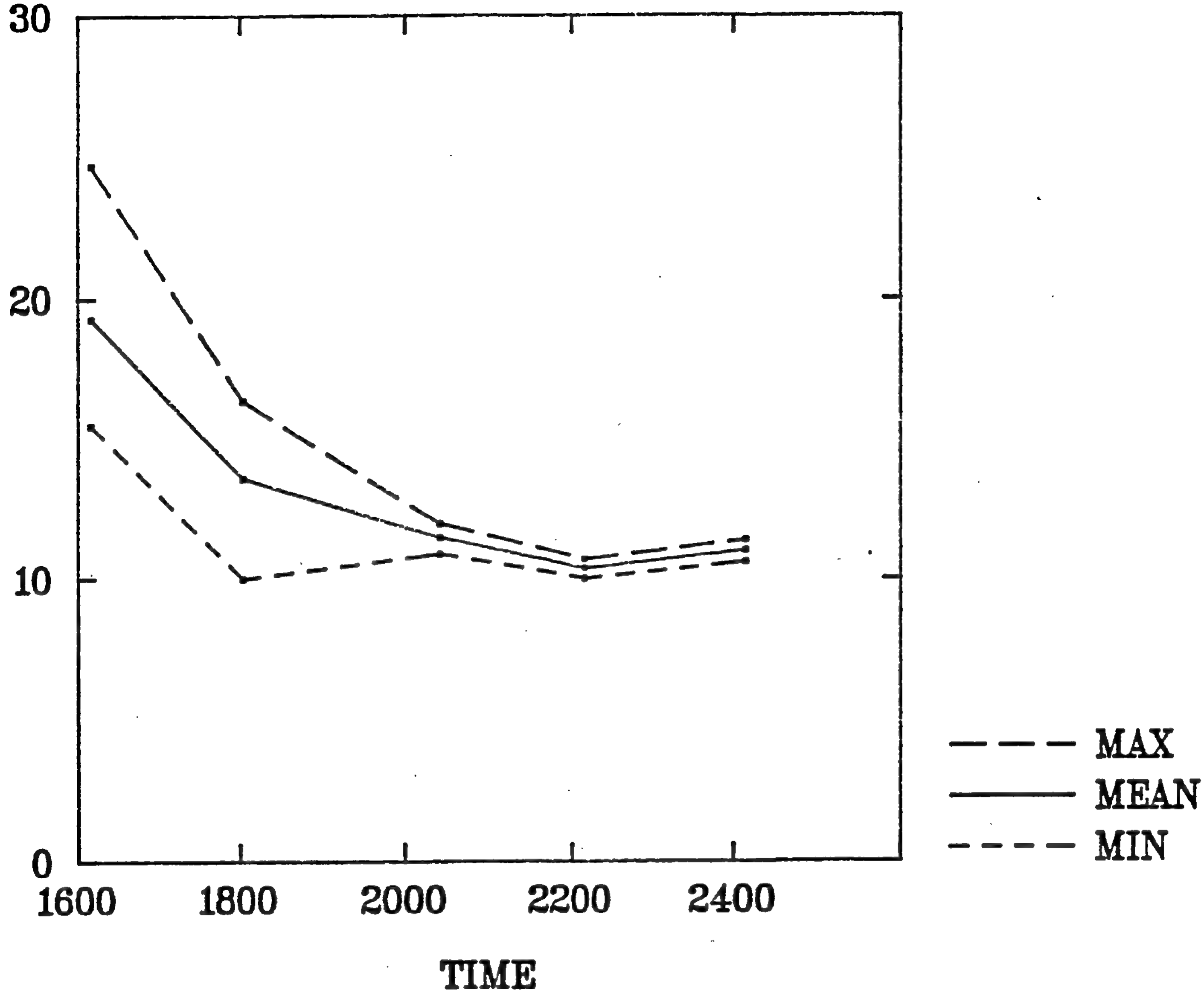



**Figure 3-3. Ground Area Apparent Temperature Statistics, 09/09/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the grassy ground area in the image foreground at the single tree site are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

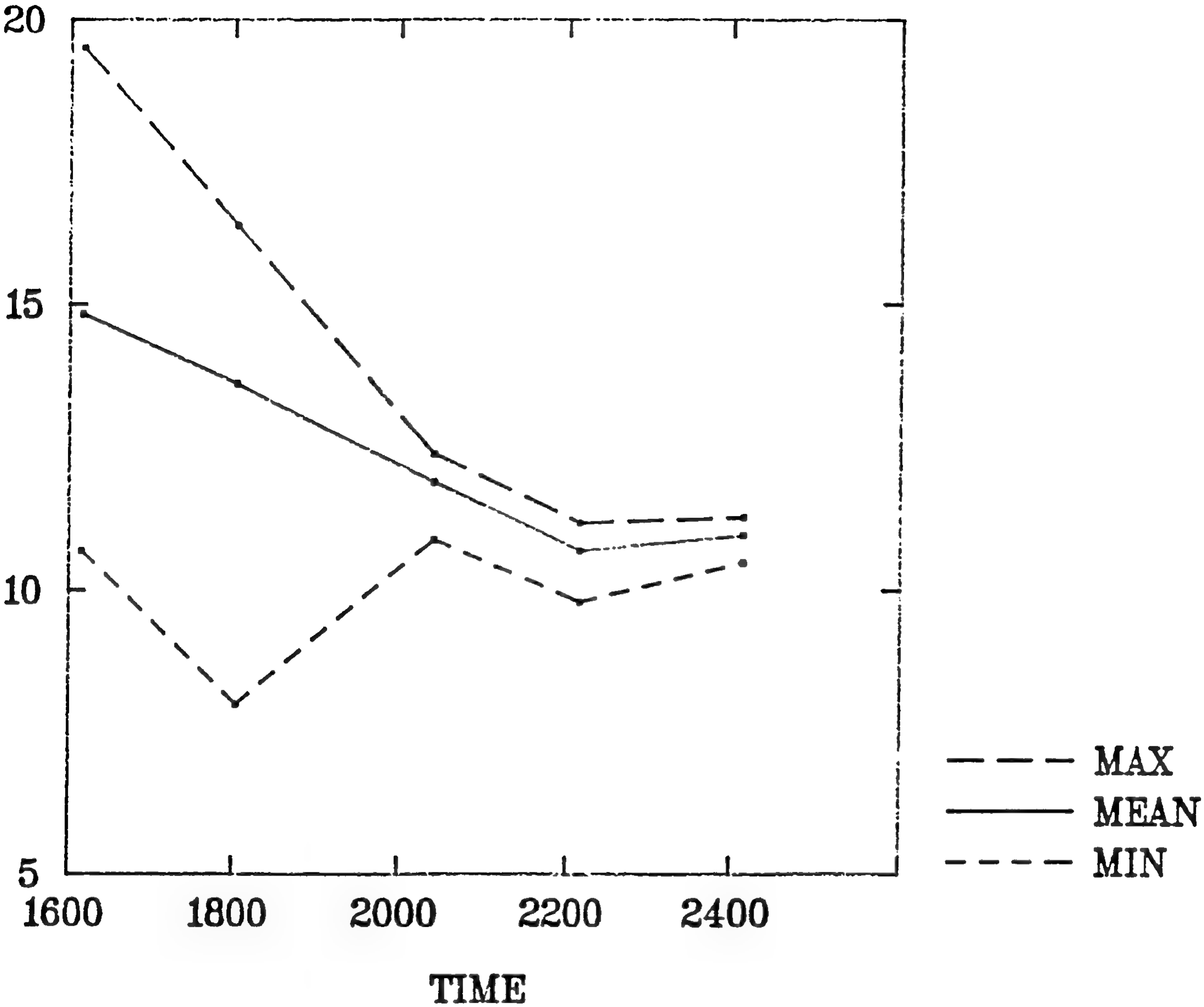



**Figure 3-4. Foreground Brush Apparent Temperature Statistics, 09/09/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the brush in the image foreground, lower right corner, at the single tree site are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

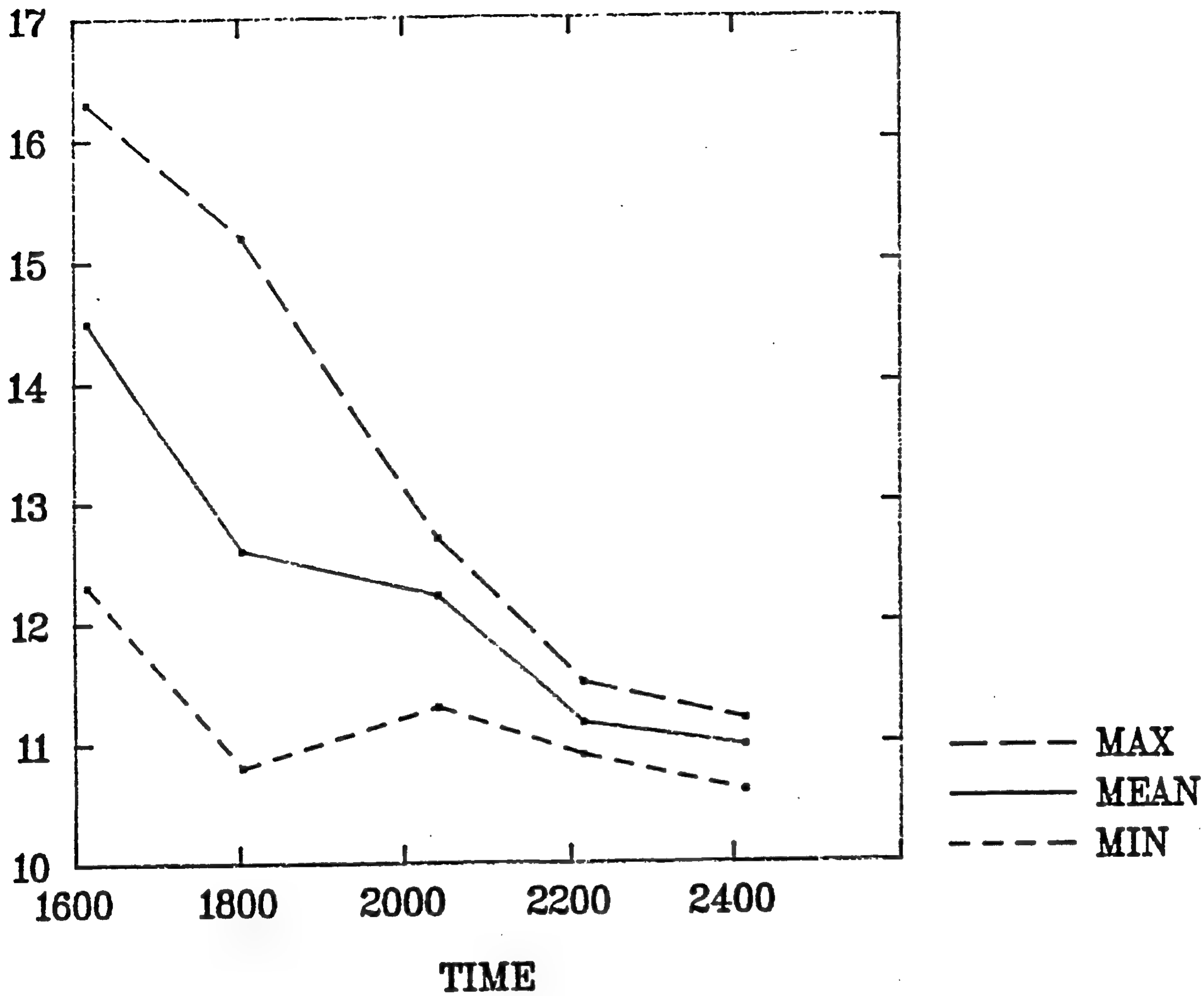



**Figure 3-5. Leaf Area Apparent Temperature Statistics, 09/09/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for specific time periods on 09 September, 1990. These times correspond to frames 08, 10, 12, 14, and 16.

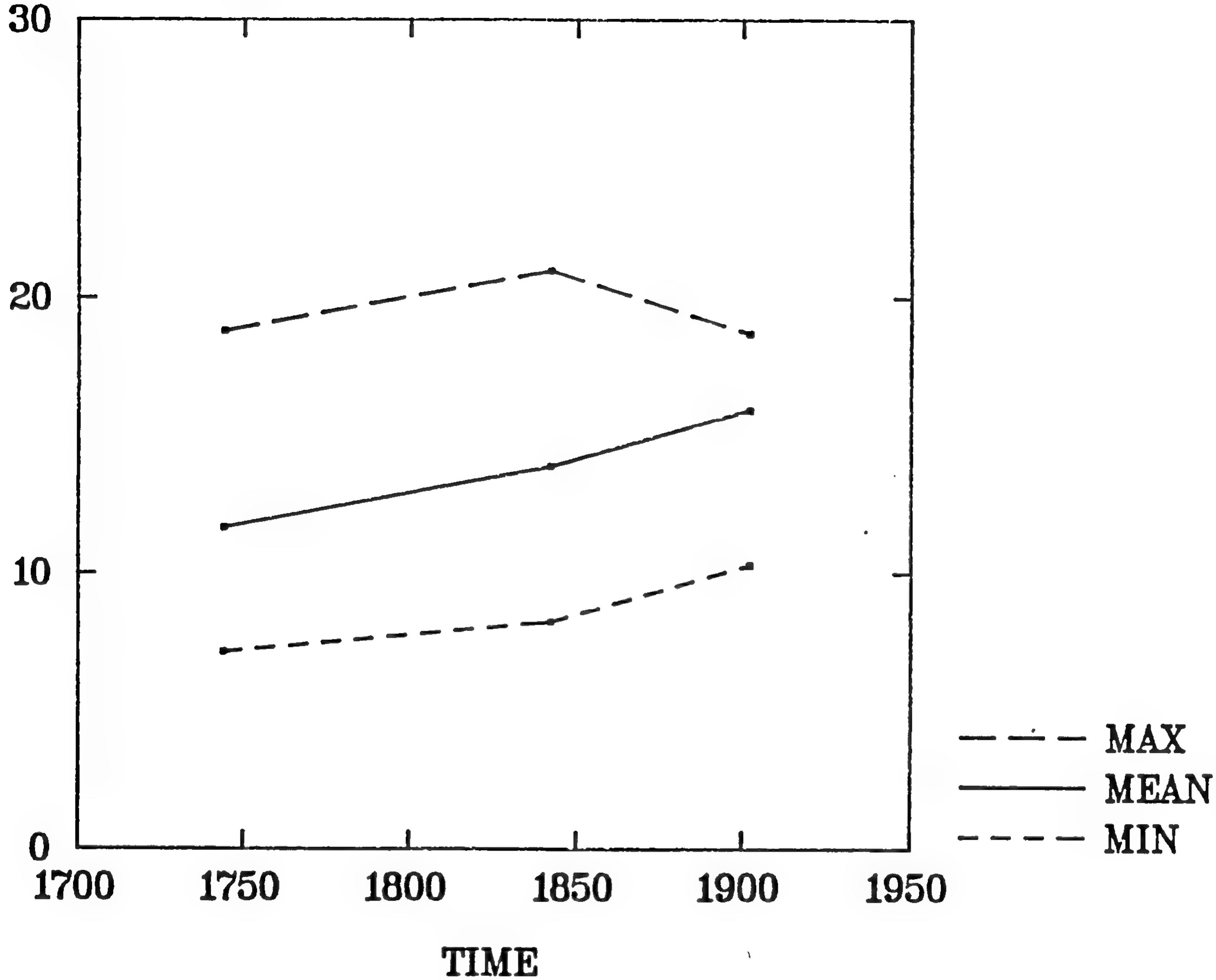



**Figure 3-6. Tree Trunk Apparent Temperature Statistics, 09/10/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the trunk of the single tree are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43 and 49.

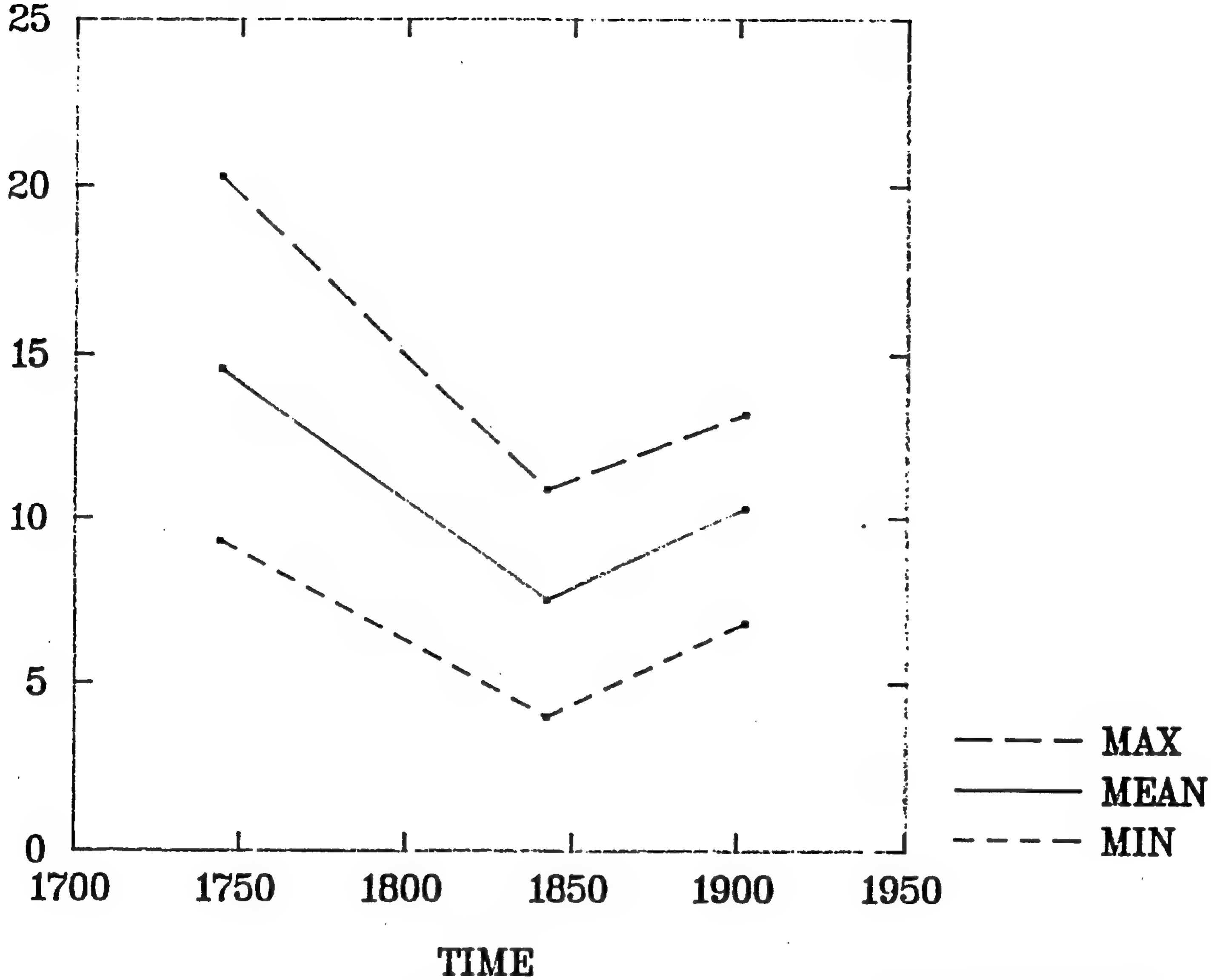



**Figure 3-7. Disturbed Soil Apparent Temperature Statistics, 09/10/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the disturbed soil area immediately to the south of the single tree are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43 and 49.

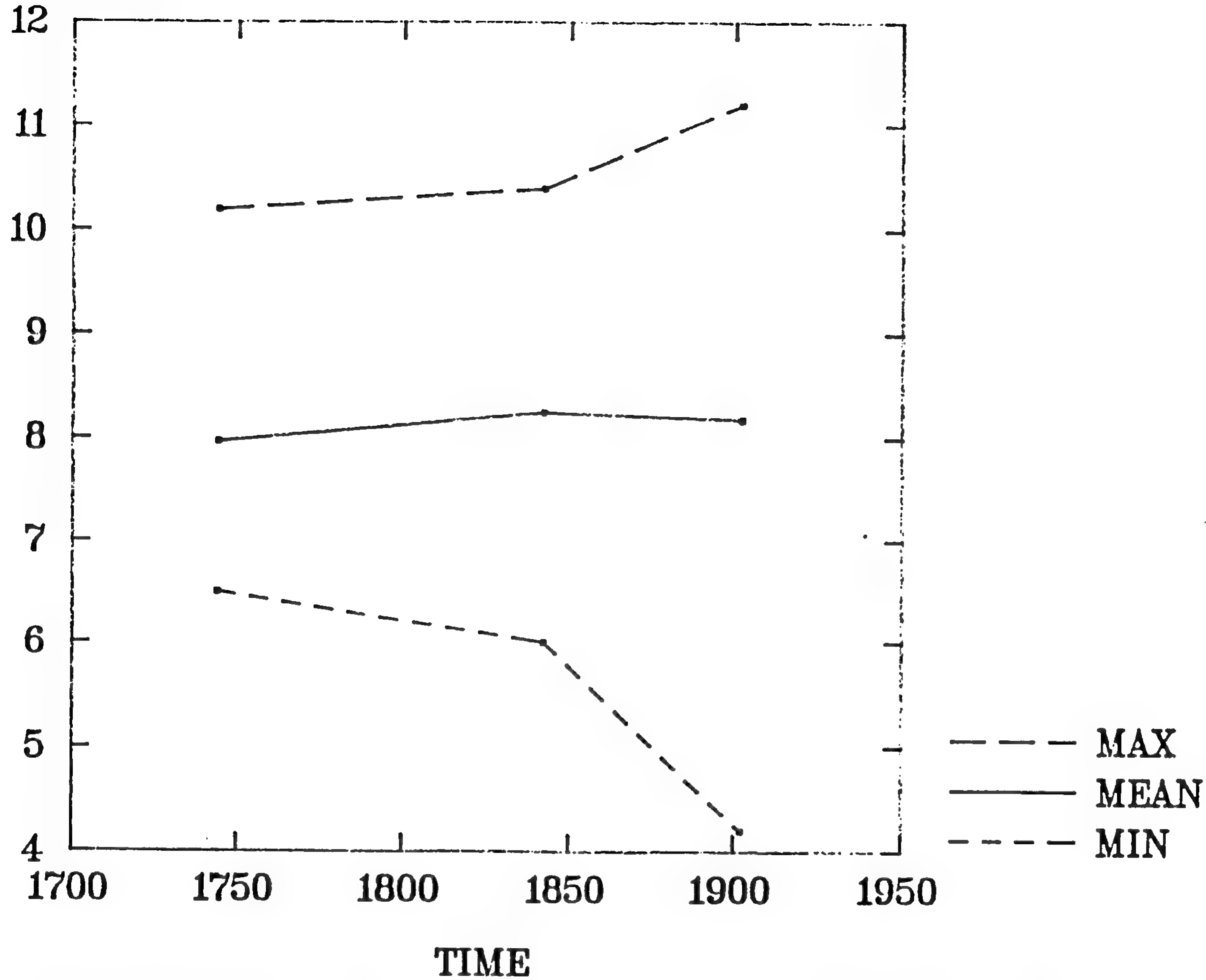



**Figure 3-8. Ground Area Apparent Temperature Statistics, 09/10/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the grassy ground area in the image foreground at the single tree site are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43 and 49.

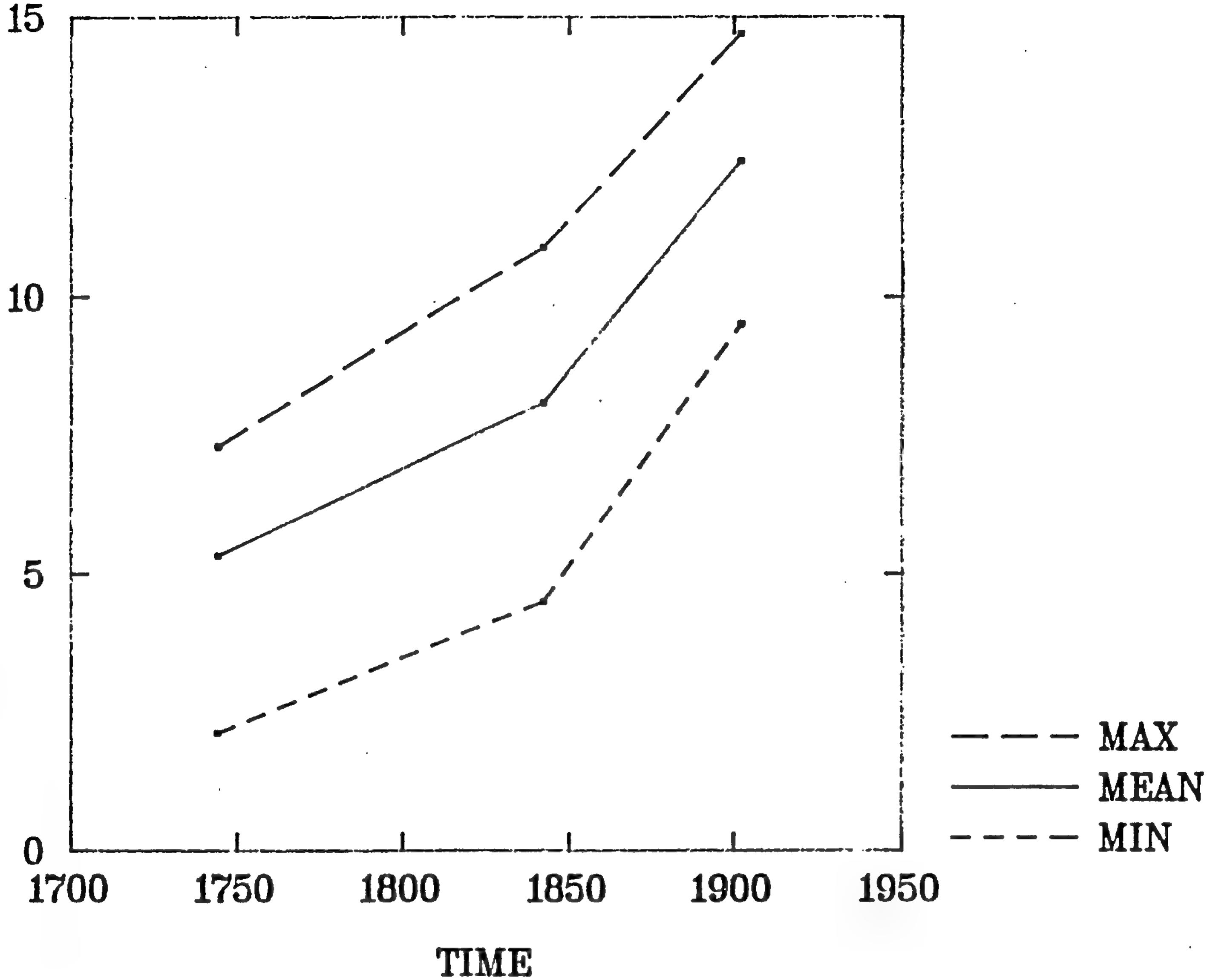



**Figure 3-9. Foreground Brush Apparent Temperature Statistics, 09/10/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for the brush in the image foreground, lower right corner, at the single tree site are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43, and 49.

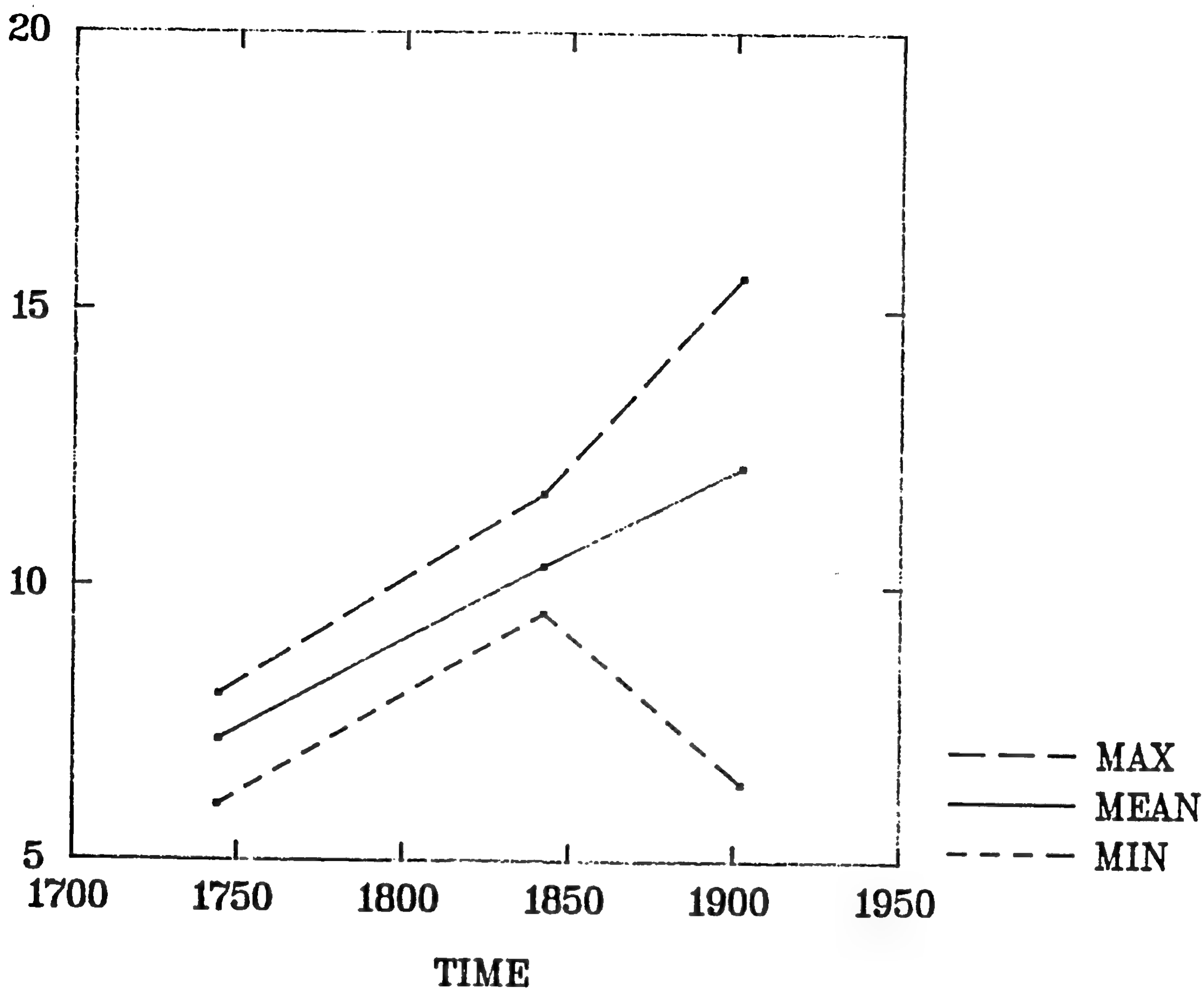



**Figure 3-10. Leaf Area Apparent Temperature Statistics, 09/10/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for specific time periods on 10 September, 1990. These times correspond to frames 37, 43, and 49.

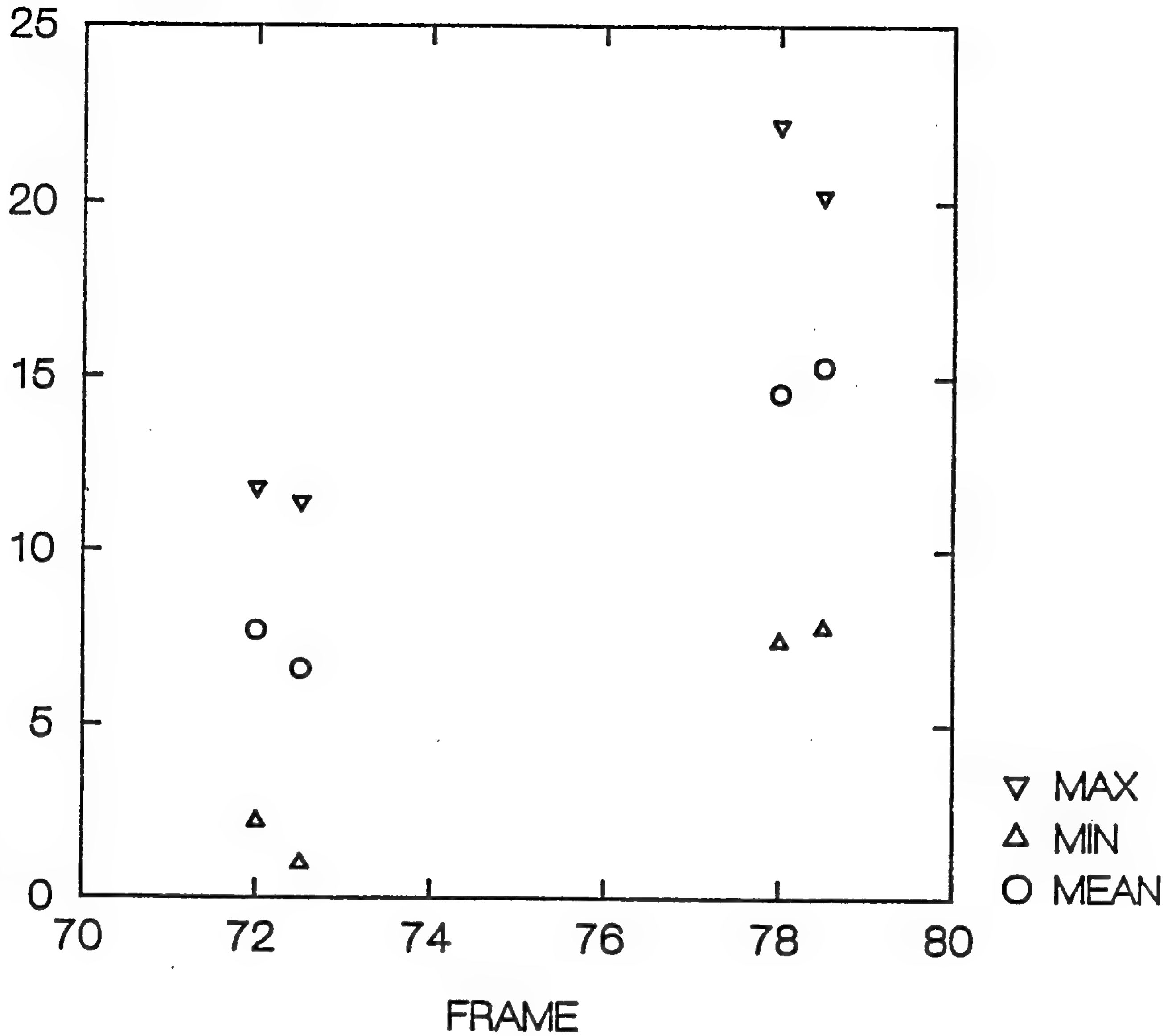



**Figure 3-11. Leaf Area Apparent Temperature Statistics, 09/11/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for pairs of images obtained during time periods with variable cloud cover on 11 September, 1990. Leaf area is on center/right portion of imaged tree crown, and has good southern exposure. Image pairs are taken from frames 72 and 78.

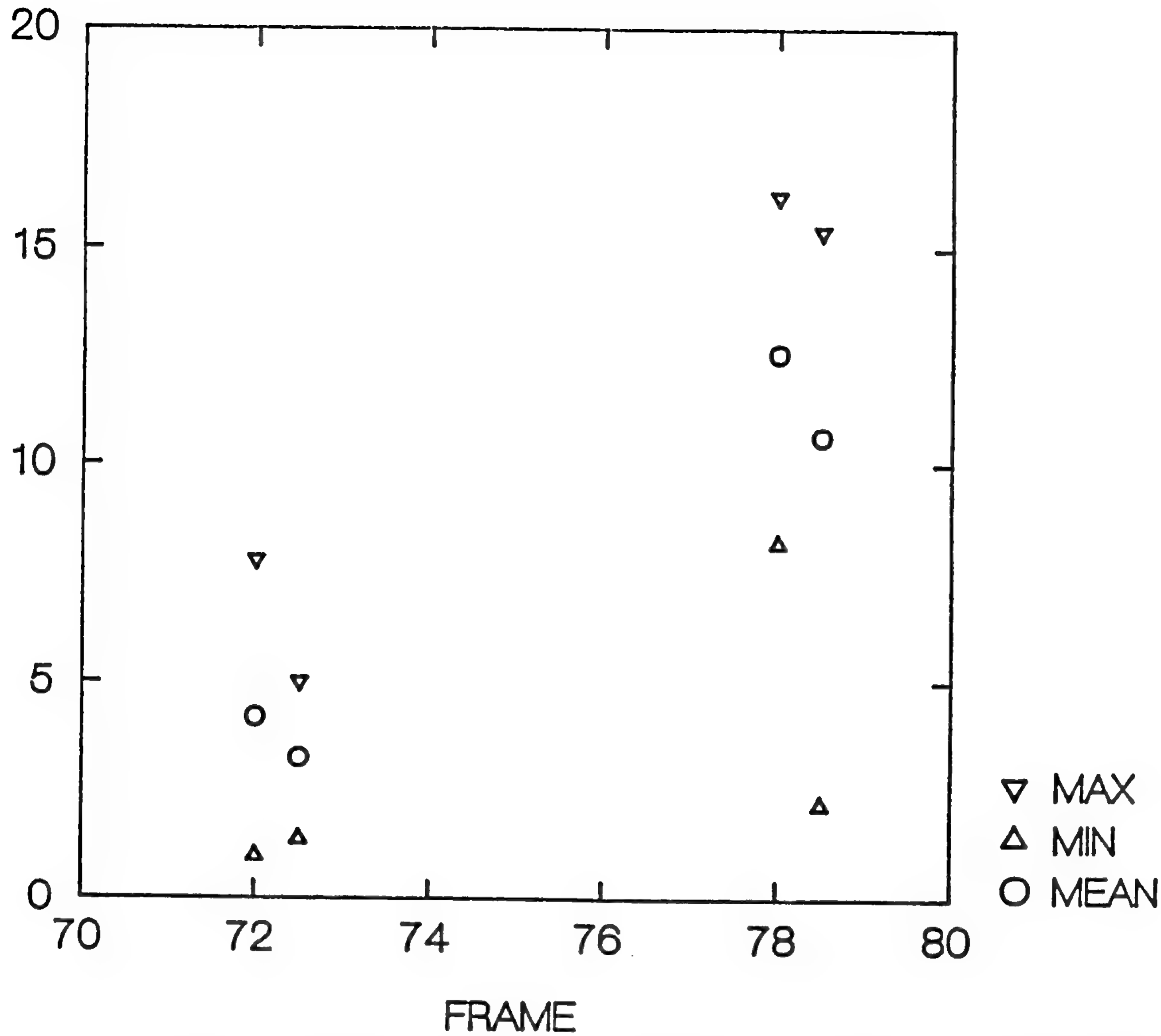



**Figure 3-12. Second Leaf Area Apparent Temperature Statistics, 09/11/90**

Maximum, mean, and minimum apparent temperatures, in degrees Celsius, for a leaf area on the single tree are shown for pairs of images obtained during time periods with variable cloud cover on 11 September, 1990. Leaf area is on left portion of imaged tree crown, with more northern exposure. Image pairs are taken from frames 72 and 78.

# Appendix C

# Standard Scenes Database

**SUBJECT:** Imagery Database and Supplementary Information

## C.1. Background on Standard Scenes

A database on six Standard Scenes was developed for the U.S. Army Tank-Automotive Command (TACOM)by the Keweenaw Research Center (KRC). Background information on the Standard Scenes program at KRC can be obtained in the U.S. Army Tank-Automotive Command Research, Development and Engineering Center Technical Report No. 13482, "Standard Scenes Program for Establishing a Natural Scenes Data Base", by W. R. Reynolds, A. M. L. LaHaie, and R. K. Baratono (1989). Content and formats of files in the Standard Scenes database are summarized in the following sections. Table C.1. provides an overview of the contents of the Standard Scenes database.

## C.2. Elevation data

C.2.1. Data Format. The topography of each Standard Scene is presented in contour maps and cross-sectional elevation maps. Contour maps are shown in Figures C.1 through C.6. Elevation data for the field containing the areas designated as Standard Scenes I, II, and III, respectively, also have been described in terms of a grid with the following specifications:

- o resolution = 10 meters (m), i.e., elevation values are given for points every 10 m in the x- and y-directions
- o magnetic North lies in positive direction of y-axis
- o approximate dimensions of the field are: 370 m wide (east-west, or x-direction), and 470 m long (north-south, or y-direction)

Two separate files, each of which contains complete elevation data, are provided. These files differ in format and in the amount of supplementary information provided; you may find one format preferable over the other for your purposes.

C.2.1. ELEV.DAT Elevation Data File. This file contains a 38x48 matrix of elevation values. Each element in the matrix represents the elevation at an intersection point in the (10 m resolution) grid overlay of the field. Element (1,1) in the grid corresponds to the southwestern corner of the field. The image of the field is oriented to coordinate axes in the standard position; thus, element (1,1) is located in the lower left corner of the image.

**ELEV.DAT File Format and Description.**

Record 1: File identifier, and brief description. Variables in the header, and their format, are as shown on page C-13.

**Table C.1: Summary of Standard Scenes Data**

| SCENE NO. | DATE | TIME | #FRAMES | TARGET |
|---|---|---|---|---|
| I | 11/11-11/12, 1983 | 1130-1430 | 85 | M60 |
| II | 11/15, 1983 | 1200-1730 | 14 | M60 |
| III | 11/15, 1983 | 1200-1730 | 5 | - |
| II | 11/16, 1983 | 1000-1700 | 20 | M60 |
| III | 11/16, 1983 | 1000-1700 | 7 | M60 |
| IV | 11/17, 1983 | 1300-2230 | 24 | M60 |
| IV | 11/18, 1983 | 0730-1200 | 6 | M60 |

Notes: Hourly weather, incomplete solar irradiance data.

| | | | | |
|---|---|---|---|---|
| II | 07/19-07/20, 1984 | 0700-0800 | 52 | - |
| III | 07/19-07/20, 1984 | 0700-0800 | 52 | - |
| I | 07/25-07/26, 1984 | 0600-0600 | 75 | M2-APC |
| IV | 08/01-08/02, 1984 | 0600-0600 | 75 | M2-APC |
| V | 08/09-08/10, 1984 | 0600-0600 | 25 | M2-APC |

Notes: Right side of M2-APC in Scenes I and IV, Front in Scene V, 48 thermocouples placed on the M2-APC.

| | | | | |
|---|---|---|---|---|
| I | 05/12-05/13, 1985 | 0800-0700 | 23 | M113-APC |
| IV | 05/14-05/15, 1985 | 0800-0800 | 12 | M113-APC |
| V | 05/16-05/17, 1985 | 0700-0700 | 32 | M113-APC |
| II | 05/18-05/19, 1985 | 0630-0700 | 32 | M113-APC |
| III | 05/19-05/20, 1985 | 0800-0700 | 31 | M113-APC |
| VI | 05/21-05/22, 1985 | 0700-0700 | 18 | M113-APC |

Notes: Gaps exist in the imagery, 43 thermocouples on the M113-APC.

| | | | | |
|---|---|---|---|---|
| V | 10/21-10/22, 1986 | 0700-0700 | 50 | M113-APC |
| IV | 10/23-10/24, 1986 | 0700-0700 | 25 | M113-APC |
| II | 10/27-10/28, 1986 | 0600-0600 | 50 | M113-APC |
| III | 10/27-10/28, 1986 | 0600-0600 | 25 | - |
| I | 10/29-10/30, 1986 | 0600-0600 | 50 | M113-APC |
| VI | 11/04-11/05, 1986 | 0600-0600 | 50 | M113-APC |

Notes: Local time change from EDT to EST after SS IV test.

Non-Standard Scenes program backgound sequences (SWB and LWB)

| | | | | |
|---|---|---|---|---|
| VI | 02/16-02/17, 1988 | 0800-0700 | 150 | M2/M60A3/M151 |
| VI | 02/17-02/18, 1988 | 0800-0800 | 150 | M2/M60A3/M151 |
| VI | 02/19, 1988 | 0800-2321 | 100 | M2/M60A3/M151 |
| Grayling | 10/19-10/20 1988 | 0730-0930 | 50 | M1A1 |
| Grayling | 11/03-11/04 1988 | 0700-0930 | 50 | M1A1 |

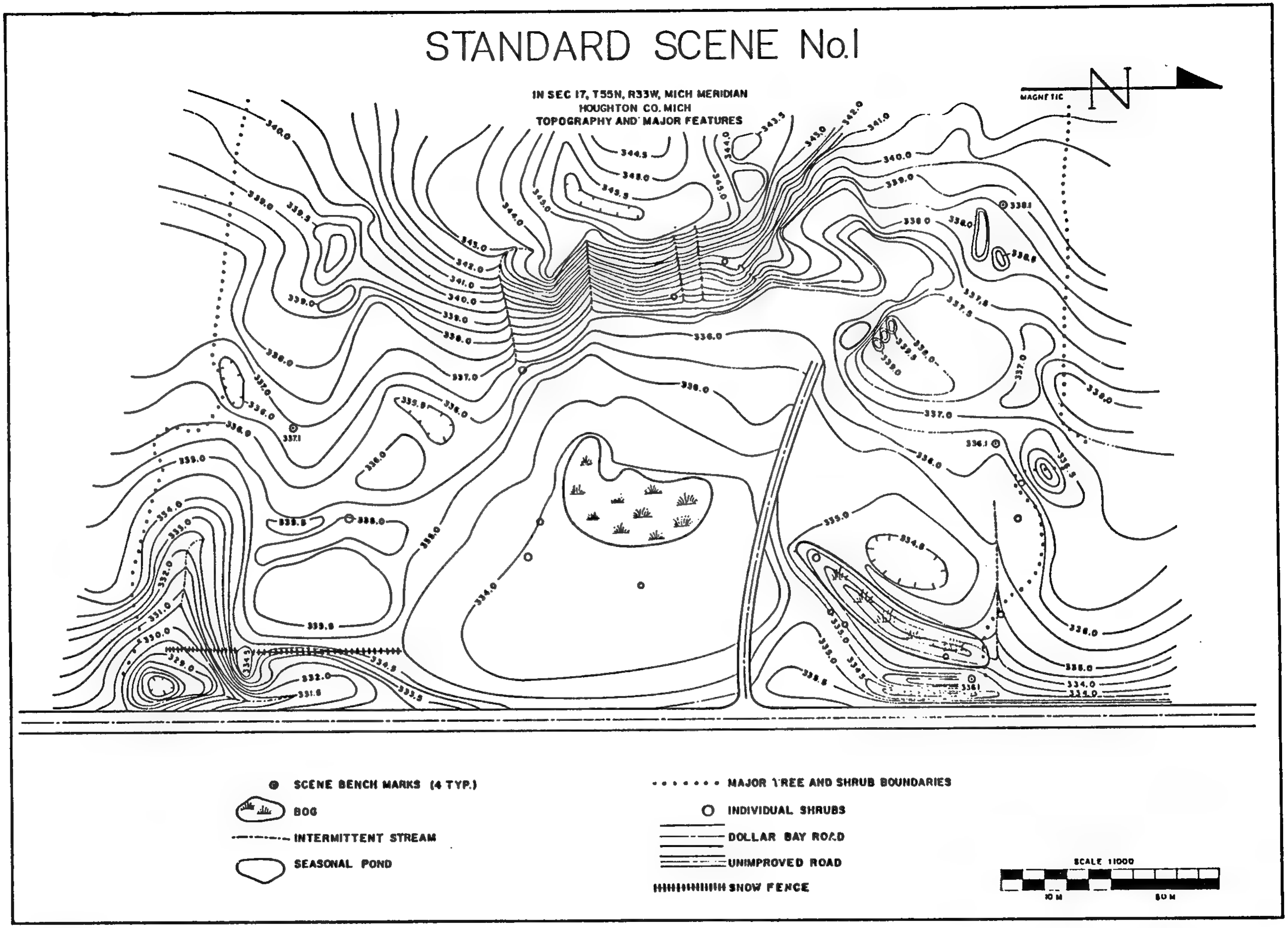



Figure C.1: Topographical Map of Standard Scene I

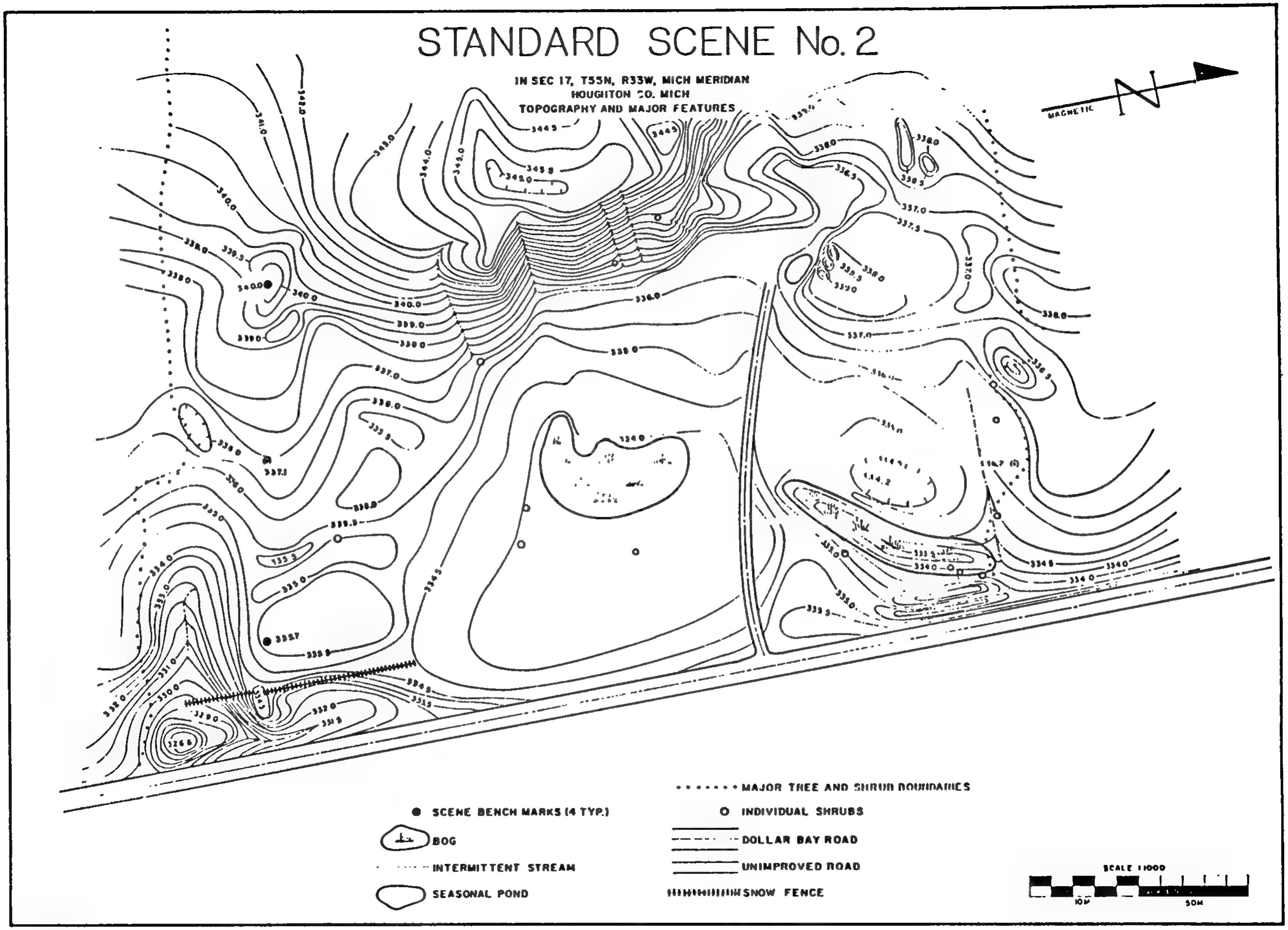


Figure C.2: Topographical Map of Standard Scene II

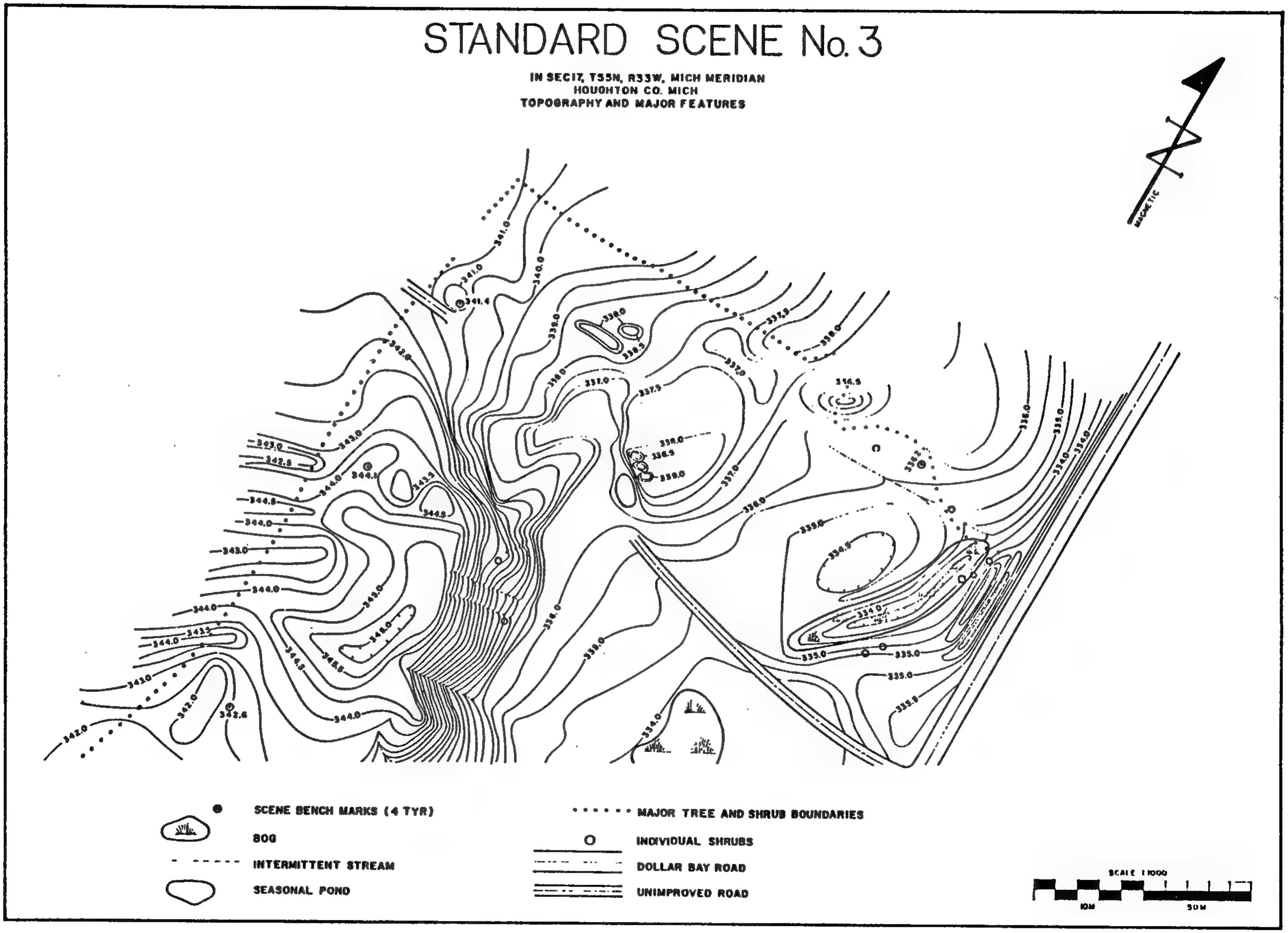



Figure C.3: Topographical Map of Standard Scene III

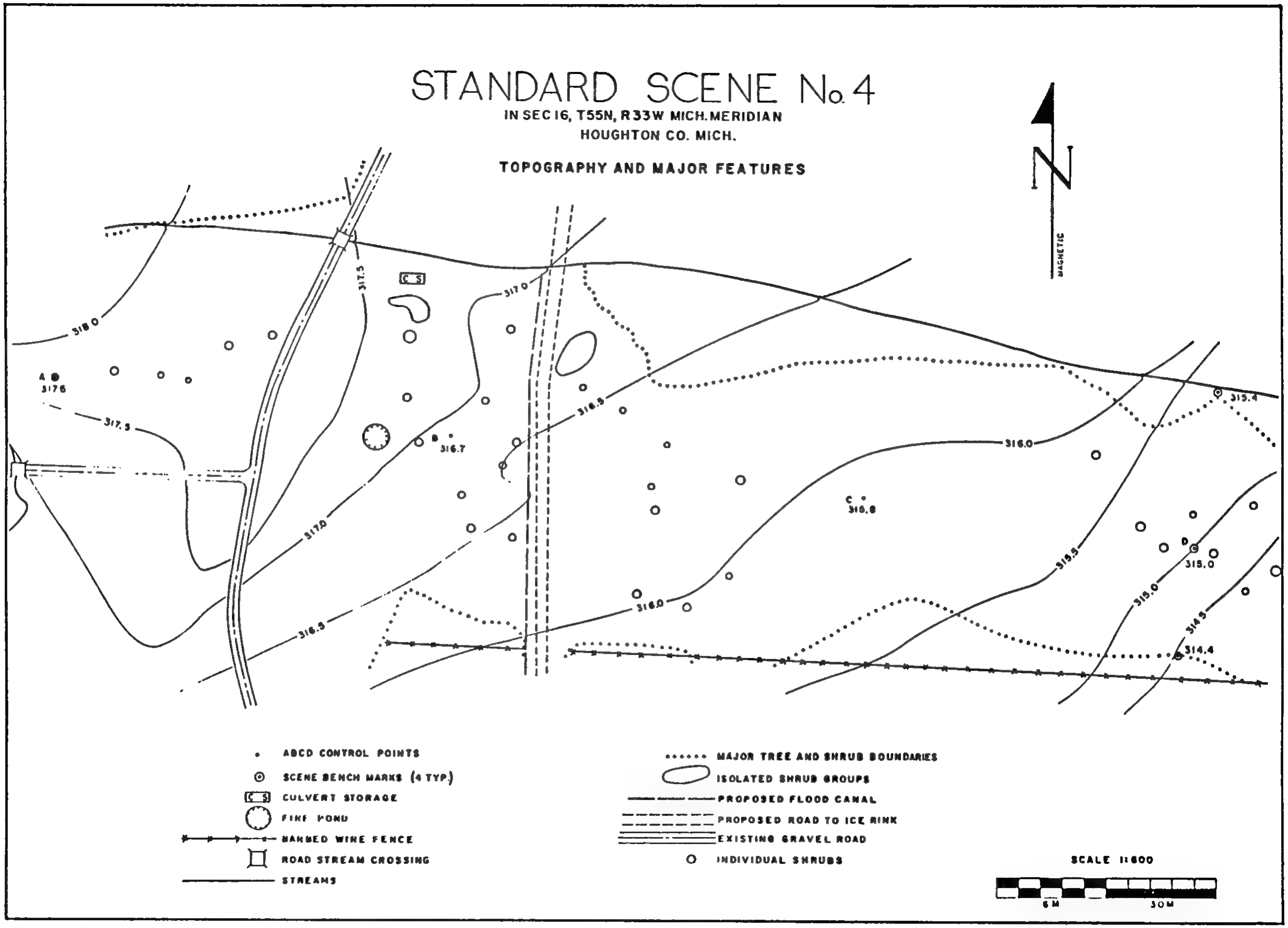



Figure C.4: Topographical Map of Standard Scene IV

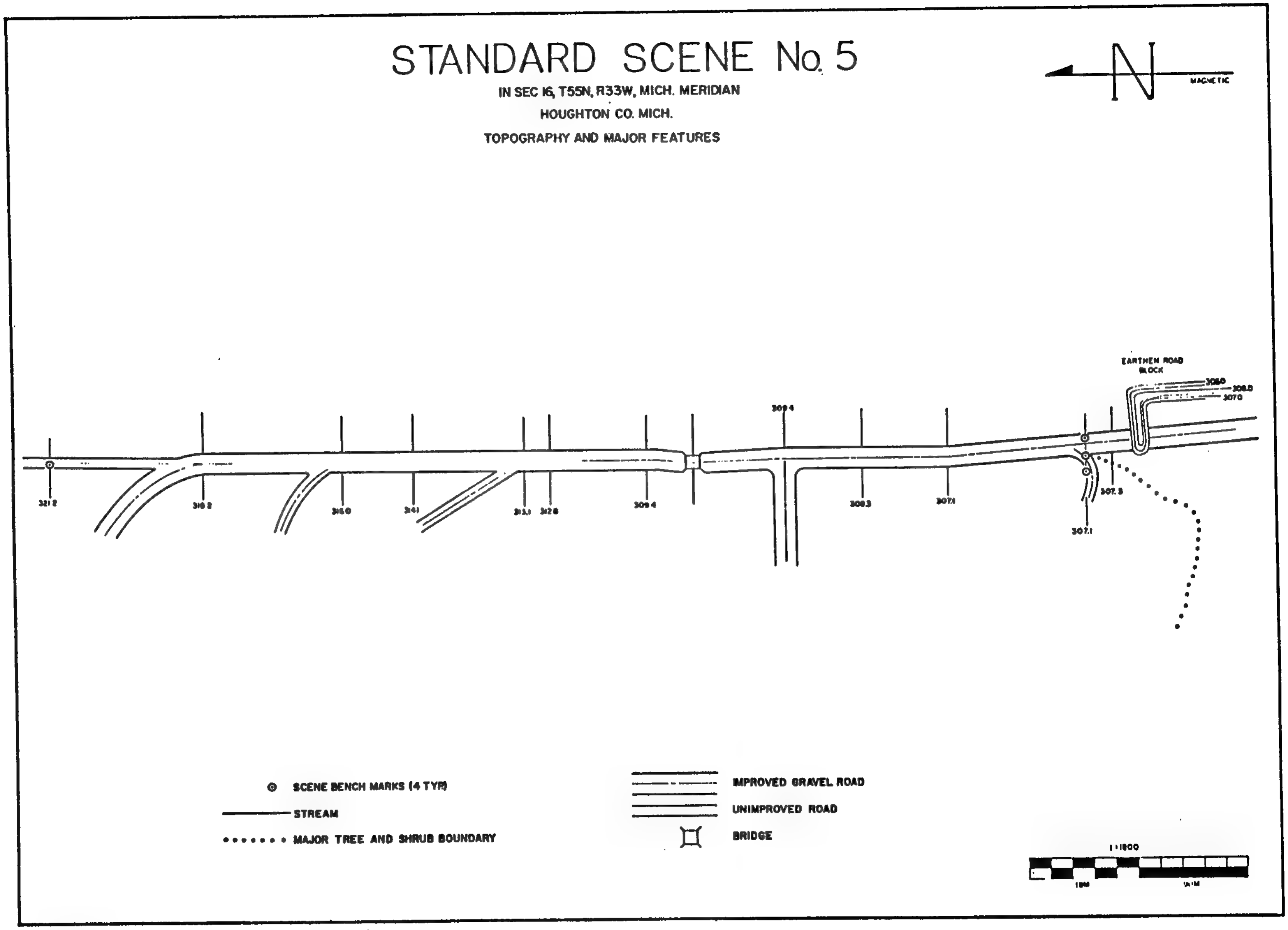



Figure C.5: Topographical Map of Standard Scene V

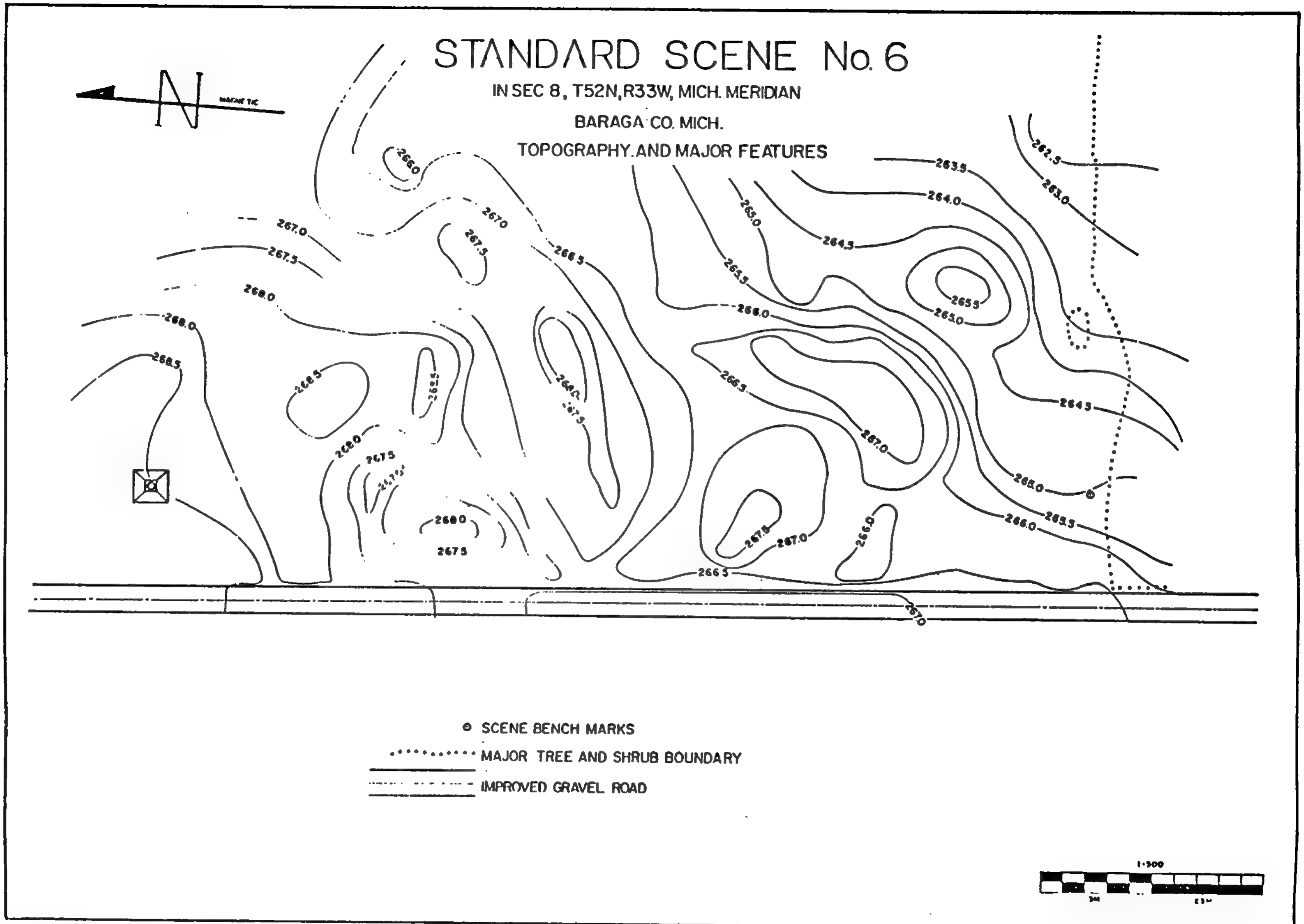



Figure C.6: Topographical Map of Standard Scene VI

(File format, Record 1 of ELEV.DAT File)

FILEID, SITEID, QUAD, N, M, UNITS, XSPACE, YSPACE, ZSCALE, LAT,LONG

FORMAT(1X,'$$',I2,1X,A10,1X,I1,1X,2I4,1X,A7,3F5.0,2F7.2).

| Variable | Definition |
|---|---|
| FILEID | Identify file as elevation matrix (= 11) |
| SITEID | Identify site that file describes |
| QUAD | Image quadrant:<br>1 : x increases to right, y to top<br>2 : x increases to left, y to top<br>3 : x increases to left, y to bottom<br>4 : x increases to right, y to bottom |
| N | Number of rows in elevation grid |
| M | Number of columns in elevation grid |
| UNITS | Units used for grid spacing |
| XSPACE | X direction grid spacing, in given units |
| YSPACE | Y direction grid spacing, in given units |
| ZSCALE | Z scale; 1 unit change in input data value value = ZSCALE units change in given units |
| LAT | Site latitude, in degrees |
| LONG | Site longitude, in degrees |

For example, the heading for the ELEV.DAT file describing the site of KRC Standard Scenes 1, 2, and 3 reads as follows:

_$$11_KRC_S1,2,3_1_   38   48_METERS_ 10.0 10.0 1.00 47.175 88.492

The following records in ELEV.DAT give NxM elevation values Z(I,J) beginning with those in row I=1, e.g.,

Z(I,1), Z(I,2), Z(I,3),..., Z(I,M)

Assuming a 38x48 matrix, each of the 38 records would contain 48 values - Z(I,1) to Z(I,48) - and would be written on six lines, with

FORMAT(5(9(1X,F7.2),/),3(1X,F7.2)).

| Variable | Definition |
|---|---|
| Z(I,J) | Elevation value at (I,J)th point of matrix or grid that overlays site |

C.2.2. ELWORLD.DAT Elevation Data File. This file gives a point-by-point description of the site in terms of local coordinates and elevations. For cross-reference purposes, matrix element information corresponding to the grid in file ELEV.DAT is also given. For the site of KRC Standard Scenes

I, II, and III, the location of the origin in local coordinates is within the boundaries of the site, an inconvenience which resulted from selecting the principal surveyor's station (Station A, located along the snow fence in the southeast portion of the field) as the (0,0) point from which all other points would be measured.

**ELWORLD.DAT File Format and Description.**

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, QUAD, UNITS, XMIN, XMAX, YMIN, YMAX, ZMIN, ZMAX, LAT, LONG

```
FORMAT(1X,'$$',I2,1X,A10,1X,I1,1X,A7,6F5.0,2F7.2).
```

| Variable | Definition |
|---|---|
| FILEID | Identify file as x,y,elevation data (= 12) |
| SITEID | Identify site that file describes |
| QUAD | Image quadrant:<br>1 : x increases to right, y to top<br>2 : x increases to left, y to top<br>3 : x increases to left, y to bottom<br>4 : x increases to right, y to bottom |
| UNITS | Units used for X, Y, and Z dimensions |
| XMIN | Minimum value of X, in given units |
| XMAX | Maximum value of X, in given units |
| YMIN | Minimum value of Y, in given units |
| YMAX | Maximum value of Y, in given units |
| ZMIN | Minimum value of Z, in given units |
| ZMAX | Maximum value of Z, in given units |
| LAT | Site latitude, in degrees |
| LONG | Site longitude, in degrees |

For example, the heading for the ELEV.DAT file describing the site of KRC Standard Scenes 1, 2, and 3 reads as follows:

```
_$$12_KRC_S1,2,3_1_METERS_-350. 20.0-50.0420.0326.8350.3 47.175 88.492
```

Thus, X ranges from -350 to 20, and Y ranges from -50 to 420. A simple translation of axes using X'= X+350.0 and Y'= Y+50.0 would move the local origin to the southwest corner of the field, thus making the (1,1)th element in the grid the local (X',Y') origin.

Each following record in ELWORLD.DAT gives coordinate values for a single point in the grid. Variables in each record are:

I, J, X, Y, Z(I,J)

```
FORMAT(2(1X,I3),3(1X,F7.2)).
```

| Variable | Definition |
|---|---|
| I | Row number of matrix element to which this point corresponds (cf. ELEV.DAT file) |
| J | Column number of matrix element to which this point corresponds (cf. ELEV.DAT file) |
| X | X value in local coordinates, given units |
| Y | Y value, local coordinates, given units |
| Z(I,J) | Elevation value at (I,J)th point of matrix or grid that overlays site, in given units above sea level. |

## C.3. Soil Data

C.3.1. Soil Physical and Thermal Characteristics. Soil types present in this site are sand or sand with silt or loam content. A single category of "sand" is adequate to describe the soil at the site. Characteristics are reported along with those for vegetation, in Section C.4.2.

C.3.2. Soil Surface Temperature Distribution. Some data on soil surface temperature distributions could be obtained from bare patches of sand visible in thermal imagery. This is recorded along with information on vegetation class temperature distributions, in Section C.4.3.

C.3.3. Soil Temperature at Various Depths, Across Time. A soil probe was placed on-site during field tests to record soil temperature at various depths. Information on soil temperature for the entire (24-hour) test day is given for each day included in the sample. You may find the entire set of data useful, or simply select the data for the specific time periods that you are modeling. Data is contained in the following files:

| File name | Description |
|---|---|
| T072584. | Standard Scene I, on 25-26 July, 1984 |
| T071984. | Standard Scene II, on 19-20 July, 1984 |
| T071984. | Standard Scene III, on 19-20 July, 1984 |
| T080184. | Standard Scene IV, on 01-02 August, 1984 |
| T080984. | Standard Scene V, on 09-10 August, 1984 |
| T051285. | Standard Scene I, on 12-13 May, 1985 |
| T051885. | Standard Scene II, on 18-19 May, 1985 |
| T051985. | Standard Scene III, on 19-20 May, 1985 |
| T051485. | Standard Scene IV, on 14-15 May, 1985 |
| T051685. | Standard Scene V, on 16-17 May, 1985 |
| T052185. | Standard Scene VI, on 21-22 May, 1985 |
| T102986. | Standard Scene I, on 29-30 October, 1986 |
| T102786. | Standard Scene II, on 27-28 October, 1986 |
| T102786. | Standard Scene III, on 27-28 October, 1986 |
| T102386. | Standard Scene IV, on 23-24 October, 1986 |
| T102186. | Standard Scene V, on 21-22 October, 1986 |
| T110486. | Standard Scene VI, on 04-05 November, 1986 |

**Tnnnnnn. Soil Temperature File Format and Description.**

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, DATE, UNITS

FORMAT(1X,'$$',I2,1X,A10,1X,I6,1X,A7).

| Variable | Definition |
|---|---|
| FILEID | Identify file as soil temp data (= 13) |
| SITEID | Identify site that file describes |
| DATE | Month, Day, and Year (MMDDYY) of test |
| UNITS | Units of Measure for temperature |

Each following one-line record gives data for one time period, in the following format:

TIME, TSURF, T1, T5, T10, T20, T50

FORMAT(I4,6(2X,F7.3))

| Variable | Definition |
|---|---|
| TIME | Time at which soil temp measurements are taken. Interval between readings is 5 min. |
| TSURF | Soil Temperature at Surface |
| T1 | Soil Temperature at 1 cm depth |
| T5 | Soil Temperature at 5 cm depth |
| T10 | Soil Temperature at 10 cm depth |
| T20 | Soil Temperature at 20 cm depth |
| T50 | Soil Temperature at 50 cm depth |

## C.4. Vegetation Data

C.4.1. Vegetation Class Maps. Information about the types of vegetation occurring in each scene is summarized on vegetation maps on same scale as topographic maps.

**Vegetation Types and Classification Codes.** Types of vegetation are listed below, along with the corresponding classification codes (cf. the ARTBASS codes).

| Ground Cover | Code |
|---|---|
| Grass | 2 |
| Wooded | 6 |
| Shrub | 10 |
| Bog | 12 |
| Moss | 15 |
| Sand (bare) | 36 |

Note more detailed plant survey information about type and percent ground cover of vegetation in, e.g., moss-dominated portions of the field is available if desired.

C.4.2. Vegetation Class Physical and Thermal Characteristics. Typical values for a variety of class properties are given in the table below. Where only one value is given, it may be interpreted as the typical, or average, value; otherwise, the pair of values represent the range of typical values.

**Table of Vegetation and Soil Characteristics.**
Typical values or ranges of typical values are shown.

| TYPE | MEASURE | MIN. | MAX. | UNITS |
|---|---|---|---|---|
| NORTHWAY FINE SAND | SPECIFIC HEAT | 1100 | | J/kg-$^{o}$K |
| " | EMISSIVITY | 0.92 | | |
| " | ABSORPTIVITY | 0.60 | | |
| " - DRY | DENSITY | 1759 | | kg/m^3 |
| " - DRY | CONDUCTIVITY | 0.40 | | W/m-$^{o}$K |
| " - WET | CONDUCTIVITY | 1.08 | | W/m-$^{o}$K |
| SANDY SOIL | ALBEDO | 0.25 | | |
| FOLIAGE | ABSORPTIVITY | 0.74 | | |
| FOLIAGE | EMISSIVITY | 0.94 | 0.96 | |
| MOSS | HEIGHT | 0.01 | | m |
| MOSS | DENSITY | 14.0 | | patches/m^2 |
| MOSS | ALBEDO | 0.10 | | |
| GRASS | HEIGHT | 0.20 | | m |
| DRY GRASS-SUN | ALBEDO | 0.15 | 0.25 | |
| DRY GRASS | ALBEDO | 0.19 | 0.22 | |
| WET GRASS-SUN | ALBEDO | 0.33 | 0.37 | |
| WET GRASS | ALBEDO | 0.14 | 0.26 | |
| SHRUB | HEIGHT | 0.12 | 0.30 | m |
| SHRUB | DENSITY | 15.0 | | patches/m^2 |
| SHRUB | LEAFLENGTH | 0.05 | 0.06 | m |
| SHRUB | LEAFWIDTH | 0.03 | | m |
| SHRUB-LIVE | EMISSIVITY | 0.95 | | |
| SHRUB-DORMANT | EMISSIVITY | 0.94 | | |
| BOG | HEIGHT | 0.20 | 0.42 | m |
| BOG | DENSITY | 1548 | | patches/m^2 |
| TREE-POPULUS | HEIGHT | 12.0 | 16.0 | m |
| TREE-PINUS | HEIGHT | 14.0 | 17.0 | m |
| TREE-ACER | HEIGHT | 11.0 | 14.0 | m |
| TREE-QUERCUS | HEIGHT | 11.0 | 14.0 | m |
| TREE-POPULUS | LEAFLENGTH | 0.07 | 0.12 | m |
| TREE-POPULUS | LEAFWIDTH | 0.04 | 0.10 | m |
| TREE-ACER | LEAFLENGTH | 0.15 | | m |
| TREE-ACER | LEAFWIDTH | 0.15 | | m |
| TREE-QUERCUS | LEAFLENGTH | 0.12 | | m |
| TREE-QUERCUS | LEAFWIDTH | 0.08 | | m |

C.4.3. Vegetation Class Temperature Distributions. Temperature information on the various vegetated areas in each Standard Scene were obtained by processing thermal imagery taken at the designated times, and calculating statistics from it. It was not possible to obtain data for all vegetation classes included on the maps by this method, so you will have to use your empirical background to supplement the data provided.

**CLASS Temperature Data File Names.** Class temperature data is contained in files specified by year and by Standard Scene:

| File name | Description |
|---|---|
| CLASS84.SS1 | Standard Scene I, on 25-26 July, 1984 |
| CLASS84.SS2 | Standard Scene II, on 19-20 July, 1984 |
| CLASS84.SS3 | Standard Scene III, on 19-20 July, 1984 |
| CLASS85.SS1 | Standard Scene I, on 12-13 May, 1985 |
| CLASS85.SS2 | Standard Scene II, on 18-19 May, 1985 |
| CLASS85.SS3 | Standard Scene III, on 19-20 May, 1985 |
| CLASS86.SS1 | Standard Scene I, on 29-30 October, 1986 |
| CLASS86.SS2 | Standard Scene II, on 27-28 October, 1986 |
| CLASS86.SS3 | Standard Scene III, on 27-28 October, 1986 |

Note that the CLASS86.SSn files are not included in the set of files that have just been sent. They or alternate files will be provided as soon as our graphics workstation facilities are available to complete the data processing.

**CLASS Temperature File Format and Description.**

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, DATE, UNITS

FORMAT(1X,'$$',I2,1X,A10,1X,I6,1X,A7).

| Variable | Definition |
|---|---|
| FILEID | Identify file as class data (= 14) |
| SITEID | Identify site that file describes |
| DATE | Month, Day, and Year (MMDDYY) of test |
| UNITS | Units of Measure for temperature |

Each following one-line record gives data for one time period, in the following format shown on the following page.

FILENAME, TIME, MEAN, STDEV, MAX, MIN, CLASS

FORMAT(F8.3,1X,F4.2,1X,F5.2,1X,F4.2,2(1X,F5.2),1X,I2)

| Variable | Definition |
|---|---|
| FILENAME | KRC archived file reference |
| TIME | Time period in which temp measurements are taken |
| MEAN | Average temperature for CLASS, this time |
| STDEV | Temperature standard Deviation for CLASS, this time period |
| MAX | Maximum temperature for CLASS, this time |
| MIN | Minimum temperature for CLASS, this time |
| CLASS | ARTBASS classification code for vegetation or soil type that is described by the preceeding statistics |

| Ground Cover | Code |
|---|---|
| Grass | 2 |
| Wooded | 6 |
| Shrub | 10 |
| Bog | 12 |
| Moss | 15 |
| Sand (bare) | 36 |

## C.5. Weather Data

C.5.1. Data on Selected Weather Parameters, Across Time. Information on selected weather parameters for the entire (24-hour) test day is given for each day included in the sample. You may find the entire set of data useful, or simply select the data for the specific time periods that you are modeling.

C.5.2. Weather File Names. Complete data on selected weather parameters, measured at 5-minute intervals throughout the test day are contained in the following files. Summary descriptions of day and nighttime conditions are included.

| File name | Description |
|---|---|
| W072584.2 | Standard Scene I, on 25-26 July, 1984<br>Warm, sunny day with few clouds<br>Clear night |
| W071984.2 | Standard Scene II, on 19-20 July, 1984<br>Warm, sunny day; high solar loading<br>Clear night |
| W071984.2 | Standard Scene III, on 19-20 July, 1984<br>Warm, sunny day; high solar loading<br>Clear night |
| W080184.2 | Standard Scene IV, on 01-02 August, 1984<br>Dense fog in AM, overcast in PM<br>Foggy night |
| W080984.2 | Standard Scene V, on 09-10 August, 1984<br>Partly cloudy, warm day<br>Partly cloudy night |
| W051285.2 | Standard Scene I, on 12-13 May, 1985<br>Mostly overcast, windy day; some rain<br>Rain at night; clearing toward morning |

| | | |
|---|---|---|
| W051885.2 | Standard Scene II, on 18-19 May, 1985 | |
| | | Clear day, light cirrus |
| | | Clouds toward morning, rain developing |
| W051985.2 | Standard Scene III, on 19-20 May, 1985 | |
| | | Partly cloudy day, clearing in PM |
| | | Clear night |
| W051485.2 | Standard Scene IV, on 14-15 May, 1985 | |
| | | Overcast, low clouds, clearing in PM |
| | | Mostly clear night, light rain at 0500 |
| W051685.2 | Standard Scene V, on 16-17 May, 1985 | |
| | | Cloudy, cold, windy; rain in early PM |
| | | Clear night |
| W052185.2 | Standard Scene VI, on 21-22 May, 1985 | |
| | | Clear day, light cirrus in early PM |
| | | Clear night |
| W102986.2 | Standard Scene I, on 29-30 October, 1986 | |
| | | Overcast day, occasional snow flurries |
| | | Clear after midnight |
| W102786.2 | Standard Scene II, on 27-28 October, 1986 | |
| | | Mostly clear day |
| | | Dense fog at night |
| W102786.2 | Standard Scene III, on 27-28 October, 1986 | |
| | | Mostly clear day |
| | | Dense fog at night |
| W102386.2 | Standard Scene IV, on 23-24 October, 1986 | |
| | | Overcast day |
| | | Mostly cloudy night, clearing by 0300 |
| W102186.2 | Standard Scene V, on 21-22 October, 1986 | |
| | | Clear day, light cirrus |
| | | Clear night, light haze early |
| W110486.2 | Standard Scene VI, on 04-05 November, 1986 | |
| | | Partly cloudy AM, clearing in late PM |
| | | Mostly cloudy night |

**Weather File Format and Description.**

Record 1: File identifier, and brief description. Variables in the header, and their format, are:

FILEID, SITEID, DATE

FORMAT(1X,'$$',I2,1X,A10,1X,I6).

| Variable | Definition |
|---|---|
| FILEID | Identify file as weather data (= 04) |
| SITEID | Identify site that file describes |
| DATE | Month, Day, and Year (MMDDYY) of test |

Each following one-line record gives data for one time period, in the following format:

TIME, AIRT, SOLAR, WIND, HUMID, HUMID, CLOUD

FORMAT(I4,5F9.0).

| Variable | Definition |
|---|---|
| TIME | Time at which soil temp measurements are taken. Interval between readings is 5 min. |
| AIRT | Air temperature in $^{o}$Celsius |
| SOLAR | Solar irradiance in Watts/$M^2$ |
| WIND | Wind speed in M/sec |
| HUMID | Relative humidity in percent (0 - 100) |
| CLOUD | Cloud cover, tenths (0=clear, 10=overcast) |

## C.6. Thermal Imagery of Standard Scenes

C.6.1. Thermal Imagery Data Files. Thermal images of each Standard Scene were taken hourly throughout the 24-hour time periods described in the "Weather" section. In some cases, additional imagery of various vehicles was also recorded, as summarized in Table C.1.

Each thermal image is contained in a file specified by Standard Scene number, date (month and year) it was recorded, and a frame number. The names of these files are in the format "S#MOYR.FRM, where "S#" states the Scene number, "MOYR" is the month and year in which the frame was recorded, and "FRM" is the frame number assigned to that image. For example, the file named "S11086.234" contains the thermal image of Standard Scene I, taken during October, 1986, with frame number 234.

**Thermal Imagery File Format and Description.**

Record 1: File identifiers, and brief description. Variables in the header, and their format are:

FRAMENO,DATE,TIME,DESCRIB,RANGE

FORMAT(5X,I5,11X,I6,1X,I4,6X,A20,5X,I4).

where:

| Variable | Definition |
|---|---|
| FRAMENO | Frame number assigned to image |
| DATE | Month, day, year (MMDDYY) of test |
| TIME | Time of day (24-hour clock) |
| DESCRIB | Brief description of image contents |
| RANGE | Temperature range ($^{o}$C). Common values are 2, 5, 10, 20, 50, 100, or 200$^{o}$C. |

The remaining records in the file give line-by-line data on pixel temperatures, in a 128x128 pixel format for files from 1984 and 1986, and in a 256x256 pixel format for files from 1985. The format of the pixel apparent temperature data is given by the statements that follow:

PTEMP(I,J)

FORMAT(M(K(16I5,/)))

where I=1,2,...,N

N=128 for 1984 and 1986 files
N=256 for 1985 files

J=1,2,...,M

M=128 for 1984 and 1986 files
M=256 for 1985 files

K=N/16

and

| Variable | Definition |
|---|---|
| PTEMP(I,J) | Temperature of the pixel in $i^{th}$ row, $j^{th}$ column of the image. Value is stated as: $(^{o}K.) * 10$. |

Image rows and columns are numbered as in matrix notation, beginning in the upper left-hand corner of the image as it is viewed on the screen. A pixel value of PTEMP(I,J)=0 indicates a border pixel, not an element of the image.

# Appendix D

# Scene Metrics with "SCENEMEZ" Software

**Texture Segments and Texture Metrics Calculated from Standard Scenes Imagery**

January, 1991

Keweenaw Research Center
Michigan Technological University
Houghton, Michigan

## 1.0 INTRODUCTION

The following is a summary report describing work performed at the Keweenaw Research Center (KRC) to generate scene metrics as part of Smart Weapons Operability Enhancement (SWOE) Program. The infrared imagery used for this purpose is described, and the image texture segments obtained from this imagery are detailed. The KRCMEZ program used to generate texture statistics is briefly described in Section 3.

## 2.0 IMAGERY AND TEXTURE SEGMENT FILES

Imagery for which scene metrics were generated was originally obtained during a 1986 field test performed at the Keweenaw Research Center (KRC) Standard Scene VI, located in the northern portion of Michigan's Upper Peninsula. Figures 1.1, 1.2, and 1.3 depict the topography, elevation (cross-sectional view), and general vegetation features, respectively, of Standard Scene VI. Imagery was obtained from the vantage of a 30 meter tower using an AGA thermal imager operating in the 8-12 um band.

The foreground of Standard Scene VI consists of a uniform field of tall grasses and clover. The treeline at the edge of this field is predominantly deciduous along the south face. The centerline viewing direction is set at $175.4^{o}$ from north.

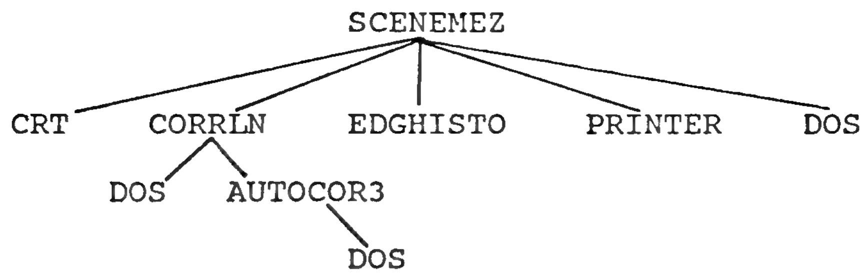
An area at the far end of the field was imaged once each hour for 24 consecutive hours. This imagery was digitized and converted to temperature frames (see Reynolds, et al., 1989). The field test took place 04-05 November, 1986, so trees are bare of leaves and the grass is dry and brown. It should be noted that images from early morning hours (0300-0500) contain very little actual temperature differentiation: apparent variations of temperature in these images are more significantly indicative of noise than are images from other time periods in the day.

For the purpose of generating scene metrics, two texture areas were sampled from each image: trees in the treeline, and tall grass in the open field in the foreground. Texture segment files in the necessary format were generated by processing binary image files through the KRC "os7" image processing software.

Standard Scene VI imagery was selected for inclusion in this work principally because of the depression angle afforded by viewing the scene from a tower. The 1986 diurnal sequence of imagery was particularly appropriate because all input data was available in the format required by the SCENEMEZ scene metrics program. Thermal imagery obtained by KRC during its participation in the 1990 Forest Ecosystem Dynamics Multisensor Aircraft Campaign (FED MAC) Experiment in Howland, Maine, is also well suited to this application and scene metrics are presently being generated from this data.

## 3.0 COMMENTS ON KRCMEZ PROGRAM

The KRCMEZ program is a variation of the SCENEMEZ program, the complete unit structure of which is shown below:




where crt, dos, and printer are standard units of Turbo Pascal 5.0; corrln, edghisto and autocor3 are units written by Waterways Experiment Station (WES) personnel.

One limitation encountered with the original SCENEMEZ.PAS software was that it required use of gray level values as input, and the input of the thermal calibration information. The program then performed its own conversion of gray levels to apparent temperatures. Since most of the imagery generated by KRC has already been converted to frames of apparent temperature values, it was suggested to WES that the program would have wider applicability if it were altered to handle either files of gray level values or files of temperature values. Such a change was introduced in the code for the KRCMEZ.PAS version of this program.

Use of the Pascal programming language may in itself pose something of a limitation. Inasmuch as a great deal of code used on imaging systems is in the C language, it might be worthwhile to convert the entire program to C and thus make it more compatible with related applications.

## 4.0 DESCRIPTION OF TEXTURE SEGMENT FILES

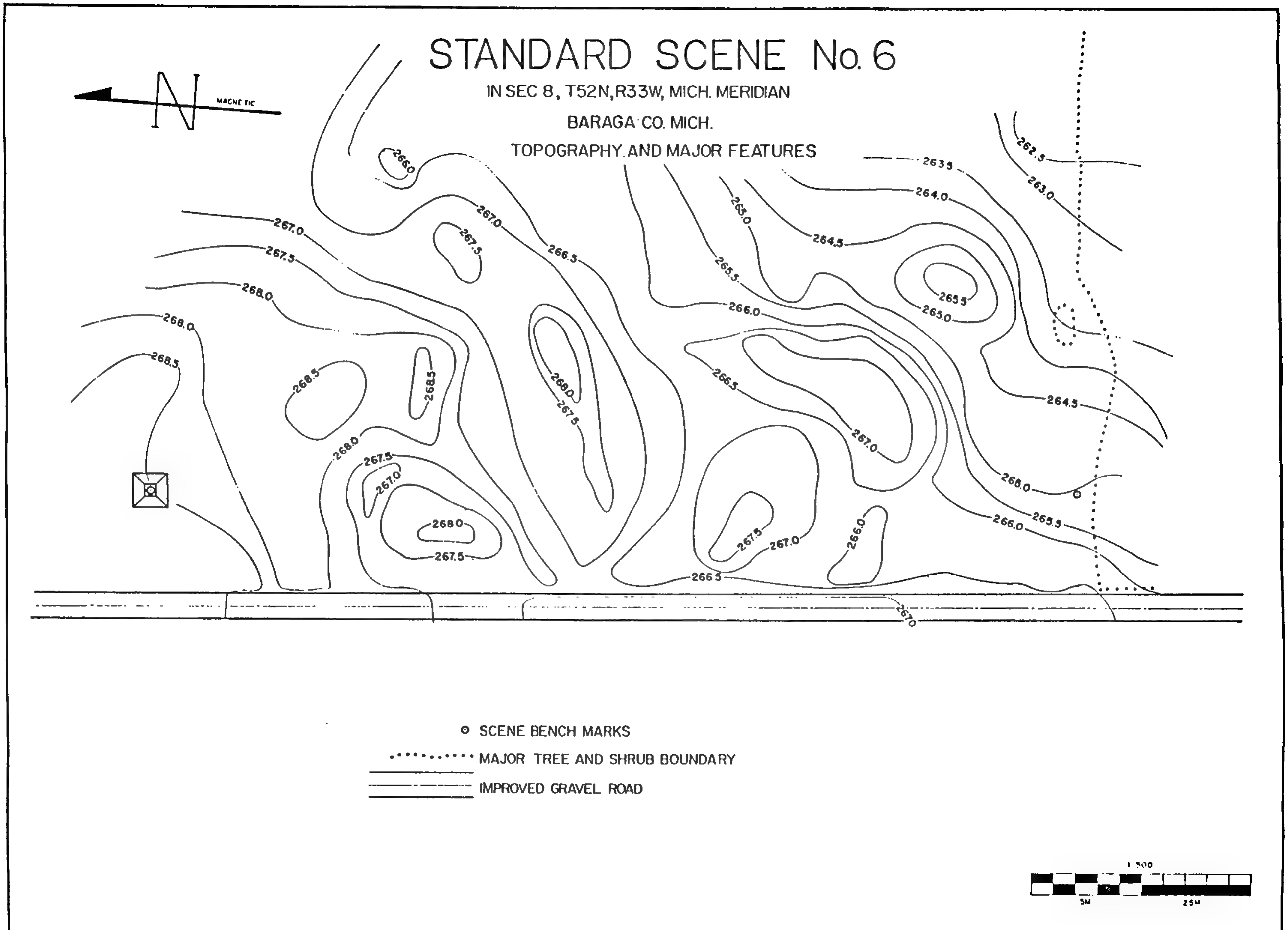
Pertinent information regarding digitized image frames used to create texture segment files is given in Table 4.1. Table 4.2 continues to elaborate the texture segment files, themselves. The information contained in Tables 4.1 and 4.2 represents required inputs to the KRCMEZ program, and details on the definitions of various inputs may be found in the program. Data was obtained from field test logs and digitizing logs, or calculated for specific images and texture segments.

Table 4.3 lists filenames for statistics output files generated for each texture segment. Both the texture segment files and their corresponding output files have been copied onto the accompanying disk. Texture segment data is gray level values from a digitized scale of 0-255. Output statistics are expressed in degrees Celsius.

REFERENCE

William R. Reynolds, Anne Marie L. LaHaie, & Robert K. Baratono, "Standard Scenes Program for Establishing A Natural Scenes Data Base", U.S. Army Tank-Automotive Command RD&E Technical Report No. 13482, Keweenaw Research Center, Houghton, MI, December 1989. (Approved for Public Release: Distribution is Unlimited.)

**Figure 1.1 Topographical Map of KRC Standard Scene VI**



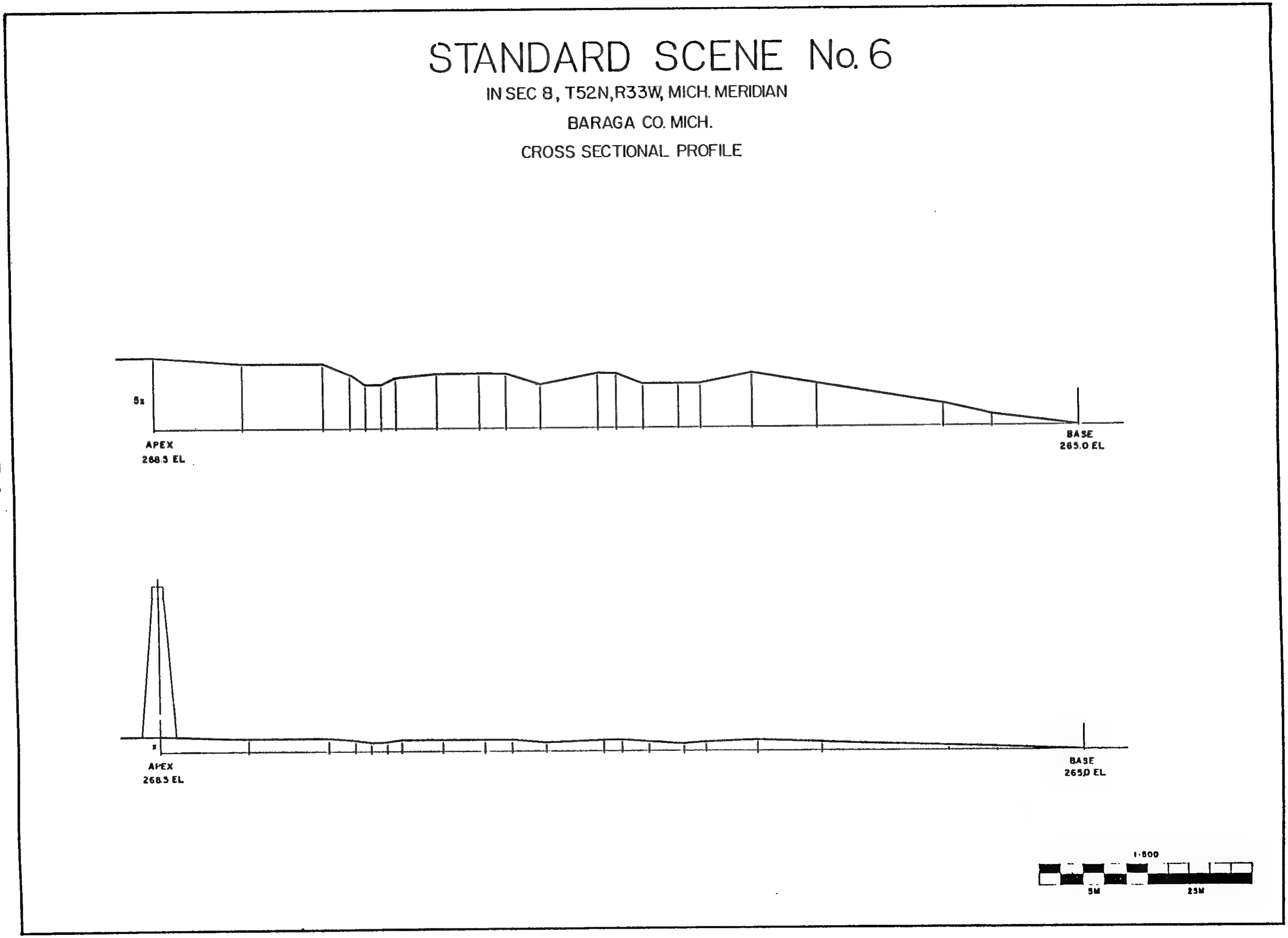



Figure 1.2 Cross-Sectional Elevation Map of KRC Standard Scene VI

Figure 1.1 Vegetation Map of KRC Standard Scene VI

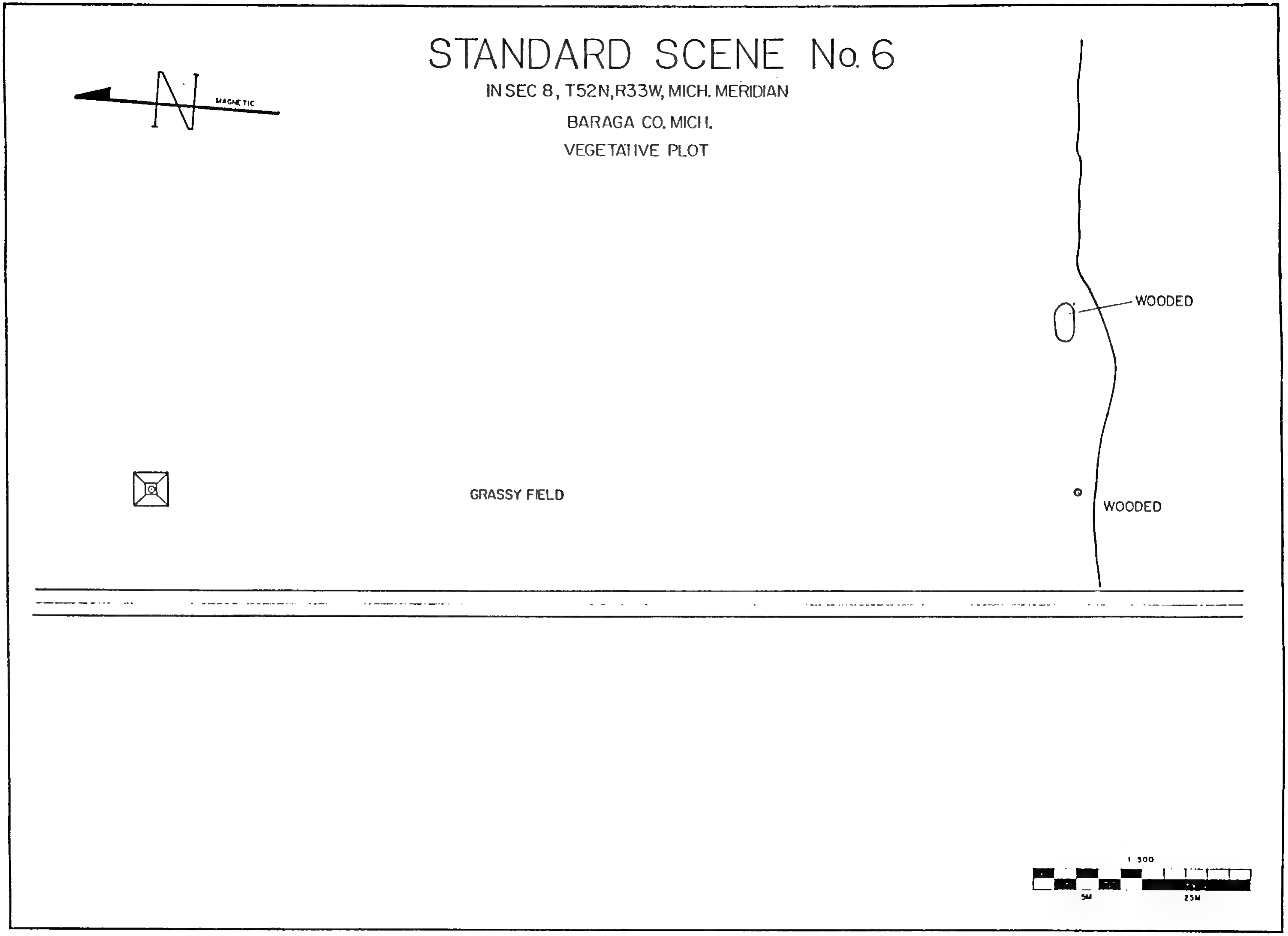


**TABLE 4.1 Image Parameter Inputs for Infrared Images**

The following data details each of the infrared image files processed by KRC to create texture segment files. Image files are referenced by their frame number, indicated by the "EXT" column below.

Page 1 of 2

| EXT nnn | DATE mm/dd/yr | HOUR hhmm | WEATHER xxxxxxxxxxxxxxxxxxxxxxxxxxxxx | FOV deg | PIX cnt | AZ deg | DEP deg |
|---|---|---|---|---|---|---|---|
| 001 | 11/04/86 | 0600 | Broken clouds 0.40 sky cover | 8 | 92 | 175 | 7.52 |
| 007 | 11/04/86 | 0700 | Scatter clds 0.60 sky cover | 8 | 92 | 175 | 7.52 |
| 012 | 11/04/86 | 0800 | Broken clouds 0.90 sky cover | 8 | 92 | 175 | 7.52 |
| 017 | 11/04/86 | 0900 | Overcast 0.95 sky cover | 8 | 92 | 175 | 7.52 |
| 023 | 11/04/86 | 1000 | Overcast 0.90 sky cover | 8 | 92 | 175 | 7.52 |
| 028 | 11/04/86 | 1100 | Broken Clouds 0.85 sky cover | 8 | 92 | 175 | 7.52 |
| 035 | 11/04/86 | 1200 | Broken clouds 0.80 sky cover | 8 | 92 | 175 | 7.52 |
| 041 | 11/04/86 | 1300 | Broken clouds 0.25 sky cover | 8 | 92 | 175 | 7.52 |
| 047 | 11/04/86 | 1400 | Scatter clds 0.15 sky cover | 8 | 92 | 175 | 7.52 |
| 053 | 11/04/86 | 1500 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 059 | 11/04/86 | 1600 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 061 | 11/04/86 | 1603 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 067 | 11/04/86 | 1700 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 073 | 11/04/86 | 1800 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 081 | 11/04/86 | 1900 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 089 | 11/04/86 | 2001 | Mostly clear 0.10 sky cover | 8 | 92 | 175 | 7.52 |
| 095 | 11/04/86 | 2100 | Mostly Clear 0.10 sky cover | 8 | 92 | 175 | 7.52 |
| 101 | 11/04/86 | 2200 | Mostly Clear 0.10 sky cover | 8 | 92 | 175 | 7.52 |
| 107 | 11/04/86 | 2300 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 113 | 11/04/86 | 0000 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 119 | 11/04/86 | 0059 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 125 | 11/04/86 | 0200 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 133 | 11/04/86 | 0300 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 141 | 11/04/86 | 0359 | Clear 0.00 sky cover | 8 | 92 | 175 | 7.52 |
| 147 | 11/04/86 | 0500 | Overcast 1.00 sky cover | 8 | 92 | 175 | 7.52 |
| 153 | 11/04/86 | 0600 | Overcast 1.00 sky cover | 8 | 92 | 175 | 7.52 |

**TABLE 4.1 Image Parameter Inputs for Infrared Images,** Continued

The following data details each of the infrared image files processed by KRC to create texture segment files. Image files are referenced by their frame number, indicated by the "EXT" column below.



| EXT nnn | TCALIB 0.nnnn | WAVEBND 8-12um | DYN cnt | GLV int | ATMP real |
|---|---|---|---|---|---|
| 001 | 0.11 | 8-12um | 256 | 76 | -5.4 |
| 007 | 0.11 | 8-12um | 256 | 80 | -5.8 |
| 012 | 0.24 | 8-12um | 256 | 133 | -5.7 |
| 017 | 0.24 | 8-12um | 256 | 170 | -4.4 |
| 023 | 0.26 | 8-12um | 256 | 153 | -2.9 |
| 028 | 0.26 | 8-12um | 256 | 147 | -1.5 |
| 035 | 0.12 | 8-12um | 256 | 118 | 0.9 |
| 041 | 0.083 | 8-12um | 256 | 103 | 1.6 |
| 047 | 0.27 | 8-12um | 256 | 90 | 2.4 |
| 053 | 0.56 | 8-12um | 256 | 94 | 2.5 |
| 059 | 0.034 | 8-12um | 256 | 110 | 2.6 |
| 061 | 0.059 | 8-12um | 256 | 101 | 2.5 |
| 067 | 0.24 | 8-12um | 256 | 111 | 0.3 |
| 073 | 0.17 | 8-12um | 256 | 99 | -2.0 |
| 081 | 0.32 | 8-12um | 256 | 113 | -2.5 |
| 089 | 0.12 | 8-12um | 256 | 130 | -1.6 |
| 095 | 0.19 | 8-12um | 256 | 108 | -2.1 |
| 101 | 0.40 | 8-12um | 256 | 102 | -1.4 |
| 107 | 0.11 | 8-12um | 256 | 103 | -2.3 |
| 113 | 0.048 | 8-12um | 256 | 111 | -1.8 |
| 119 | 0.068 | 8-12um | 256 | 113 | -1.8 |
| 125 | 0.082 | 8-12um | 256 | 115 | -1.8 |
| 133 | 0.046 | 8-12um | 256 | 112 | -1.8 |
| 141 | 0.057 | 8-12um | 256 | 119 | -1.2 |
| 147 | 0.018 | 8-12um | 256 | 90 | -1.0 |
| 153 | 0.0039 | 8-12um | 256 | 86 | -0.2 |

**TABLE 4.2 Image Texture Segment File Inputs**

Two texture segment files were created from each of the image files described in Table 4.1. Texture segment file names in the format **FVI86nnn.S0x** specify a **F**rame from Standard Scene **VI** taken in 19**86**, frame number **nnn** (corresponding to the "EXT" numbers listed in Table 4.1). The filename extension indicates a **S**egment of type **x** where x=1 is trees, and x=2 is the grassy foreground.



| FILENAME FVI86nnn.S0x | ANGL deg | RNGM int | TEXTURE DESCRIPTION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx | ROW cnt | COL cnt |
|---|---|---|---|---|---|
| FVI86001.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86001.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86007.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86007.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86012.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86012.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86017.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86017.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86023.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 18 | 58 |
| FVI86023.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86028.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 18 | 58 |
| FVI86028.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86035.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86035.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86041.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86041.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86047.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86047.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86053.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86053.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86059.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86059.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86061.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86061.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86067.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86067.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86073.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 18 | 58 |
| FVI86073.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 18 | 58 |
| FVI86081.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86081.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86089.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86089.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 18 | 58 |
| FVI86095.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86095.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86101.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86101.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |

**TABLE 4.2 Image Texture Segment File Inputs**, Continued

Two texture segment files were created from each of the image files described in Table 4.1. Texture segment file names in the format **FVI86nnn.S0x** specify a **F**rame from Standard Scene **VI** taken in **1986**, frame number **nnn** (corresponding to the "EXT" numbers listed in Table 4.1). The filename extension indicates a **S**egment of type **x** where x=1 is trees, and x=2 is the grassy foreground.

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| FILENAME FVI86nnn.S0x | ANGL deg | RNGM int | TEXTURE DESCRIPTION xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx | ROW cnt | COL cnt |
|---|---|---|---|---|---|
| FVI86107.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86107.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86113.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86113.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 18 | 58 |
| FVI86119.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86119.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86125.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 18 | 58 |
| FVI86125.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86133.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 18 | 58 |
| FVI86133.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 18 | 58 |
| FVI86141.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86141.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |
| FVI86147.S01 | -7.01 | 221 | BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86147.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 18 | 58 |
| FVI86153.S01 | -7.01 | 221 | ROW OF BARE TREES AT FIELD EDGE | 17 | 58 |
| FVI86153.S02 | 80.74 | 202 | FOREGROUND FIELD OF TALL GRASS | 17 | 58 |

**TABLE 4.3 Image Texture Statistics Output Files**

A unique output file of texture statistics was generated for each texture segment file. Names of texture segment input files and their corresponding statistics output files are shown. The ".SPS" extension on the output file is automatically generated by the KRCMEZ program.



| INPUT FILENAME FVI86nnn.S0x | OUTPUT FILENAME FVI86nnn.SPS |
|---|---|
| FVI86001.S01 | FVI86001.SPS |
| FVI86001.S02 | FVI86002.SPS |
| FVI86007.S01 | FVI86007.SPS |
| FVI86007.S02 | FVI86008.SPS |
| FVI86012.S01 | FVI86012.SPS |
| FVI86012.S02 | FVI86013.SPS |
| FVI86017.S01 | FVI86017.SPS |
| FVI86017.S02 | FVI86018.SPS |
| FVI86023.S01 | FVI86023.SPS |
| FVI86023.S02 | FVI86024.SPS |
| FVI86028.S01 | FVI86028.SPS |
| FVI86028.S02 | FVI86029.SPS |
| FVI86035.S01 | FVI86035.SPS |
| FVI86035.S02 | FVI86036.SPS |
| FVI86041.S01 | FVI86041.SPS |
| FVI86041.S02 | FVI86042.SPS |
| FVI86047.S01 | FVI86047.SPS |
| FVI86047.S02 | FVI86048.SPS |
| FVI86053.S01 | FVI86053.SPS |
| FVI86053.S02 | FVI86054.SPS |
| FVI86059.S01 | FVI86059.SPS |
| FVI86059.S02 | FVI86060.SPS |
| FVI86061.S01 | FVI86061.SPS |
| FVI86061.S02 | FVI86062.SPS |
| FVI86067.S01 | FVI86067.SPS |
| FVI86067.S02 | FVI86068.SPS |
| FVI86073.S01 | FVI86073.SPS |
| FVI86073.S02 | FVI86074.SPS |
| FVI86081.S01 | FVI86081.SPS |
| FVI86081.S02 | FVI86082.SPS |
| FVI86089.S01 | FVI86089.SPS |
| FVI86089.S02 | FVI86090.SPS |
| FVI86095.S01 | FVI86095.SPS |
| FVI86095.S02 | FVI86096.SPS |
| FVI86101.S01 | FVI86101.SPS |
| FVI86101.S02 | FVI86102.SPS |

**TABLE 4.3 Image Texture Statistics Output Files**, Continued

A unique output file of texture statistics was generated for each texture segment file. Names of texture segment input files and their corresponding statistics output files are shown. The ".SPS" extension on the output file is automatically generated by the KRCMEZ program.



| INPUT FILENAME | OUTPUT FILENAME |
|---|---|
| FVI86nnn.S0x | FVI86nnn.SPS |
| | |
| FVI86107.S01 | FVI86107.SPS |
| FVI86107.S02 | FVI86108.SPS |
| FVI86113.S01 | FVI86113.SPS |
| FVI86113.S02 | FVI86114.SPS |
| FVI86119.S01 | FVI86119.SPS |
| FVI86119.S02 | FVI86120.SPS |
| FVI86125.S01 | FVI86125.SPS |
| FVI86125.S02 | FVI86126.SPS |
| FVI86133.S01 | FVI86133.SPS |
| FVI86133.S02 | FVI86134.SPS |
| FVI86141.S01 | FVI86141.SPS |
| FVI86141.S02 | FVI86142.SPS |
| FVI86147.S01 | FVI86147.SPS |
| FVI86147.S02 | FVI86148.SPS |
| FVI86153.S01 | FVI86153.SPS |
| FVI86153.S02 | FVI86154.SPS |

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Keweenaw Research Center (KRC) participation in the Basic Technology Initiative Smart Weapons Operability Enhancement (BTI/SWOE) Program, including contributions in the program's three primary developmental areas, are reported and summarized. In the area of background measurement and characterization, data and results from KRC participation in the 1990 Forest Ecosystem Dynamics - Multisensor Aircraft Campaign (FED MAC) are presented. FED MAC data and KRC Standard Scenes data were prepared for incorporation to the information data base being established by the BTI/SWOE program. The Physically Reasonable Infrared Signature Model (PRISM), developed by KRC, was made available to the BTI/SWOE modeling effort. Work with software for calculating scene statistics and metrics for infrared imagery is described. Recent developments of PRISM and of image processing software are summarized.


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